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RH: Birth synchrony in Yellowstone bison • *Jones et al.*

Timing of Parturition Events in Yellowstone Bison—Implications for Bison Conservation and Brucellosis Transmission Risk to Cattle

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ABSTRACT: Yellowstone bison (*Bison bison*) are chronically infected with brucellosis (*Brucella abortus*), which raises concerns about possible transmission to cattle when they migrate to winter ranges outside Yellowstone National Park. We monitored bison from April to mid-June during 2004-2007 to estimate the timing and location of parturition events that may shed tissues infected by *B. abortus*. Observed abortions (n = 29) occurred during January through May 19, while peak calving (80% of births) occurred during April 25 to May 26 and calving was finished by June 5. Observed parturition events (n = 115) occurred in the Park and on the Horse Butte peninsula in Montana, where cattle were not present during any time of year. Allowing bison to occupy public lands outside the Park where cattle are never present (e.g., Horse Butte peninsula) until most bison calving is completed (late May or early June) is not expected to significantly increase the risk of brucellosis transmission from bison to cattle because (1) bison parturition is essentially completed weeks before cattle occupy nearby ranges, (2) female bison meticulously consume birthing tissues, (3) ultraviolet light and heat degrade *Brucella* on tissues, vegetation, and soil, (4) scavengers remove fetuses and remaining birth tissues, and (5) management maintains separation between bison and cattle on nearby ranges. Allowing bison to occupy public lands outside the Park through their calving season will help conserve bison migratory behavior and reduce stress on pregnant females and their newborn calves, while still minimizing the risk of brucellosis transmission to cattle.

SHORT COMMUNICATION

The increase of Yellowstone bison (*Bison bison*) from 23 animals in 1901 to 5000 animals in 2005 is a prominent example of conservation success (Plumb et al. 2009). However, about 40-

60% of Yellowstone bison have been exposed to the bacterium *Brucella abortus* (Treanor et al. 2007), which was likely transmitted from European cattle by 1917 (Mohler 1917). Yellowstone bison exhibit seasonal migrations along altitudinal gradients, with some bison moving from higher-elevation summer ranges inside Yellowstone National Park to lower-elevations in and outside the northern and western boundaries of the Park during winter and spring (Meagher 1989, Bruggeman et al. 2009). Bison migration outside the Park into Montana has led to an enduring series of conflicts among various publics and management entities regarding the transmission risk of *B. abortus* from bison to cattle.

Brucellosis infection of cattle results in direct economic loss to ranchers (e.g., slaughter of cattle) and indirect economic loss to Montana's cattle industry due to additional testing requirements and transport restrictions (i.e., trade) to other states (Godfroid 2002). Management agencies have attempted to conserve the migration of Yellowstone bison to lower-elevation winter ranges in Montana, while maintaining separation from cattle (U.S. Department of the Interior (USDI) & U.S. Department of Agriculture (USDA) 2000, Plumb et al. 2009). To prevent the movement of bison outside established conservation zones in Montana, management agencies attempt to haze bison back into Yellowstone National Park by May 1 along the north boundary and May 15 along the western boundary using helicopters, all-terrain vehicles, snowmobiles, and horses (USDI et al. 2008).

Hazing operations occur 2-4 weeks before bison and other ungulates typically begin to migrate to higher-elevation summer ranges in the Park (Frank & McNaughton 1992, Gates et al. 2005, White et al. 2007). These forced movements place additional stress on bison that are undernourished at the end of winter and vulnerable newborn calves; especially when conditions are not yet suitable on Park summer ranges due to persistent deep snow delaying vegetation green-up. The emergence of spring vegetation in the Park coincides with the receding snowpack, which can vary annually by a few weeks (Thein et al. 2009, Watson et al. 2009). Bison migration from summer range to winter range is positively related to snow build-up on the summer range, while return migration from lower elevation winter ranges aligns with temporal and spatial patterns of plant phenology (Bjornlie and Garrott 2001, Bruggeman et al. 2006). Management agencies may be able to conserve the migratory behavior of Yellowstone bison and reduce hazing stress by extending bison access to low elevation ranges outside the Park for a few additional weeks. During years when green-up is delayed, grazing opportunities outside the Park will allow bison to begin replenishing body reserves and produce high quality milk for newborn survival while probably having little effect on the risk of brucellosis transmission to cattle.

Brucellosis is a reproductive disease in bison and transmission concerns to cattle involve the shedding of *B. abortus* infected birth tissues onto the landscape where livestock can contact the bacteria. A symptom of *Brucella* infection is the induction of late-term abortions (Williams et al. 1997), with the highly infectious fetus serving as an important source of transmission (Thorne 2001). Additionally, the placental tissues and birth fluids associated with newborn calves can be infectious, making live births a potentially important transmission source (Cheville et al. 1998, Rhyan et al. 2009). The timing and location of bison parturition events, defined here to include reproductive failures (e.g., abortions) and live births, directly affect the risk of brucellosis transmission to cattle. The purpose of this study is to identify the timing and location of bison parturition events and integrate these data with existing information on *B. abortus* persistence in the environment to help management agencies conserve bison migratory behavior and reduce hazing stress, while minimizing the risk of brucellosis transmission from bison to cattle.

Material and methods

Yellowstone National Park encompasses 8,987 km^2 in northwestern Wyoming (44º38•N, 110º51•W) and adjacent portions of Montana and Idaho, with elevations between 1,500 and 2,600 meters. We monitored 121 radio-collared, adult, female bison and non-collared, adult, females within the same social groups through calving seasons from April to mid-June during 2004-2007. Visual cues (e.g., belly size, distended udders, swollen vulva, contractions, behavior demonstrating discomfort, and tissues or fluids exuding from the vulva) were used to record pregnancy status and schedule return observations to identify parturition locations and dates. Opportunistic observations and employee and visitor reports of parturition events were also investigated within and outside the calving period.

We divided observed parturition events into three categories: 1) reproductive failures; 2) live births; and 3) radio-collared females with newborn calves. Observed reproductive failures included abortions (fetal stage), stillborn calves (near term), and females that died from complications during the birthing process. Retained placentas were used as an indicator of a reproductive failure if a calf was not observed with the female or as a live birth if a newborn calf was present. Parturition events were recorded as live births if the birth was directly observed or if the newborn calf, still wet from birth fluids, was observed being cleaned by the birthing female. The locations of the observed parturition events and dates of occurrence were recorded. Birth dates of radio-collared bison that were not directly observed were estimated based on previous observations of the pregnant female (i.e., female was pregnant within 4 days of being observed with a calf).

Results

We observed 115 bison parturition events including 54 live births (49 direct observations and 5 placenta retentions with a calf present), 29 reproductive failures (13 stillborn calves, 11 placenta retentions with no calves present, and 5 deaths of females during parturition), and 32 radio-collared females with newborn calves. Parturition events were primarily concentrated inside the Park, but 12 events occurred outside the western boundary on the Horse Butte peninsula in Montana (Figure 1). Reproductive failures occurred primarily from January through April, with 76% of observations occurring by the end of April and the latest reproductive failure observed on May 19 (Table 1). The earliest newborn calf was seen in late March or early April each year, and the last observed birth typically occurred in late May or early June. Approximately 50% of births occurred by May 6 (• 40 day period), 80% by May 16 (• 50 day period), and 95% by May 27 (• 61 day period). Eighty percent of calving occurred during the 32 days from April 25 to May 26 (Figure 2).

Discussion

Observed parturition events were concentrated in April and May and primarily occurred within Yellowstone National Park. Parturition events outside the Park were located on public land (i.e., Horse Butte peninsula) where cattle are not present at any time of year. Reproductive failures were observed from January to mid-May, covering the third trimester of pregnancy when *B. abortus*-induced abortions typically occur. Our observations of bison live births were highly synchronous, with 50% of births occurring in 15 days and 80% of cumulative births occurring in 32 days. These observations are in agreement with previous findings of high calving synchrony in Yellowstone bison, with >50% of births occurring within 13-27 days and >80% of cumulative births occurring within 23-60 days (Gogan et al. 2005). The phenomenon of reproductive synchrony, where birthing occurs in a short time frame or pulse, has been documented in a number of ungulates, including wildebeest (*Connochaetes taurinus*; Estes 1976), roe deer (*Capreolus capreolus*; Gaillard et al. 1993), moose (*Alces alces*; Bowyer et al. 1998), caribou (*Rangifer tarandus*; Adams & Dale 1998), and bison (McHugh 1958, Meagher 1973, Berger & Cain 1999). The synchrony of bison parturition events might be useful for managing bison near Yellowstone's boundaries. Brucellosis transmission from bison to cattle requires infectious birth products (e.g., birth fluids, tissues, and aborted fetuses) to be shed onto the landscape where cattle can contact them. Thus, the relative risk of transmission is the product of the number of cattle in the exposure area, the number of infectious parturition events that occur in the exposure area, and the persistence of bacteria shed by infectious events (Kilpatrick et al. 2009).

If bison and cattle do not share the same lands (i.e., exposure area) at any time, then the possibilities for brucellosis transmission are limited. Allowing bison to occupy public lands on the Horse Butte peninsula until most calving is completed (i.e., late May or early June) is not expected to increase transmission potential because cattle are not present at any time of year and agency management prevents bison from accessing nearby cattle summer ranges. The number of cattle near the Horse Butte peninsula is low during winter and spring, with no cattle in the management zone west of the Park (Kilpatrick et al. 2009, White et al. 2009). During mid-June and July, about 1,800 cattle are released onto public and private lands north and west of Yellowstone National Park (White et al. 2009), and the agencies have successfully maintained spatial and temporal separation between bison and cattle. During this period, maintaining successful separation benefits from the tendency of bison to follow the progressive green-up of grasses back into the Park interior as snow melts at higher elevations (Gates et al. 2005). The few bison that do remain on boundary ranges outside the Park are hazed back into the Park or lethally removed (USDI et al. 2008).

During our study, observed parturition events occurred weeks before the arrival of cattle on summer ranges and did not occur in areas occupied by cattle year-round or later used by cattle during summer. All observed reproductive failures, indicating the potential for highly infectious aborted pregnancies, occurred 2 to 6 weeks before cattle are released onto ranges near the Park's western boundary. Although newborn bison calves have been observed in Yellowstone in late summer, live births late in the summer are rare (Taper et al. 2000, Gates et al. 2005) and generally occur when bison have returned to the Park. These observations indicate that the main reproductive events (i.e., abortions and live births), which present the highest potential for brucellosis transmission, do not overlap with cattle occupancy at a large spatial scale. To date, there have not been any documented cases of brucellosis transmission from bison to cattle and this success may be attributed to the absence of cattle on bison winter and spring ranges, the timing of parturition events prior to cattle arrival on nearby ranges, and active prevention of bison co-mingling with cattle.

Brucella has the capacity to survive and persist in the environment under suitable conditions (Corbel 1989) and prevention of brucellosis transmission from bison to cattle should consider *B. abortus* persistence in the environment even if bison and cattle are spatially separated. Studies indicate that *B. abortus* persistence decreases rapidly with increased ultraviolet exposure, heat, and dry conditions (Cook et al. 2004). In Laramie, Wyoming, Cook et al. (2002) found that *B. abortus* survived on the protected underside of a fetus for an average of 60.5 days in February, but only 2.8 to 4.7 days in May and June. Similarly, Aune et al. (2007) found that *B. abortus* survived on fetal tissue placed near Yellowstone National Park for a maximum of 77 days in

February and 24 days in mid-May. These studies suggest that *B. abortus* persistence during summer near Yellowstone's western boundary is probably limited to a few weeks, and allowing bison to occupy public land on the Horse Butte peninsula where cattle are never present is not expected to increase the potential for brucellosis transmission.

Infected birth tissues most likely will be removed from the environment long before *Brucella* bacteria die due to the cleaning behavior of bison (Meagher 1973, Jones et al. 2009) and high scavenging rates of birth tissues and bacterial degradation (Cook et al. 2004, Aune et al. 2007, Maichak et al. 2009). During our study, observed bison birth sites covered a small area (e.g., 3 x 3 meters) and female bison meticulously cleaned birth sites by consuming all birth tissues, eating the vegetation, and licking the soil (Jones et al. 2009). This behavior reduces the quantity of viable bacteria and transmission potential because cattle, not being present at bison birth sites, would not have the opportunity to later contact infectious tissues. However, the 16 observations of retained placentas underscore the need to prevent bison from occupying lands used by cattle. Infectious tissues and fluids are not confined to parturition sites. Following parturition, discharges of vaginal exudates and placental retention can allow a postpartum bison female to contaminate a larger spatial area. The continued success of preventing brucellosis transmission from bison to cattle will require agency management to maintain separation of bison and cattle.

Scavengers also limit how long *B. abortus* will persist in tissues shed onto the landscape. The greater Yellowstone ecosystem has a diverse scavenger guild, including bears (*Ursus americanus*, *U. arctos*), coyotes (*Canis latrans*), eagles (*Aquila chrysaetos, Haleaeetus leucocephalus*), foxes (*Vulpes vulpes*), ground squirrels (*Spermopilus armatus, S. lateralis*), magpies (*Pica hudsonia*), ravens (*Corvus corax*), and wolves (*Canis lupus*). These scavengers quickly and reliably remove fetuses and birthing material from the landscape that may be infected with *B. abortus* and their protection on feed grounds in Wyoming has been suggested as a means to reduce brucellosis transmissions in elk (Maichak et al. 2009). Two studies specific to the greater Yellowstone area examined the length of time a fetus would remain on the landscape before being scavenged. Cook et al. (2004) observed 16 different scavengers consuming 100% (n = 89) of bovine fetuses in an average of 26.8 hours from the National Elk Refuge in Wyoming, 40.7 hours from the state-operated elk feed grounds in Wyoming, and 57.5 hours from Grand Teton National Park. Aune et al. (2007) found that bovine fetuses were scavenged and disappeared in an average of 7.5 days inside Yellowstone National Park and 13.0 days outside the Park during 2001. They also reported that fetuses placed outside the northern and western boundaries of the Park disappeared, on average, in 18.2 days (range = 1-78; SD = 20.1) during 2002 and 2003. Month had no effect on the length of time for fetus disappearance. Thus, we concur with Aune et al. (2007:211) that "natural environmental conditions leading to bacterial degradation and animal scavenging, conspire to kill Brucella and remove potentially infected fetal tissue from the environment by June 15."

Yellowstone bison that migrate beyond the Park's boundaries present a challenge to management agencies that are attempting to conserve bison migratory behavior, while preventing brucellosis transmission to cattle near the Park boundaries. We propose that allowing bison to remain on specified public lands outside the Park where cattle are never present (e.g., Horse Butte peninsula) until late-May or early June, when most calving is completed and bison typically begin migrating back onto Park summer ranges, is unlikely to significantly increase the risk of brucellosis transmission to cattle. Brucellosis transmission from bison to cattle has not occurred and may be due to the cumulative effects of management to maintain separation between cattle and bison, synchrony of bison parturition events (i.e., parturition concentrated in a short period, with abortion cycle earlier than the live birth cycle), bison parturition locations (i.e., spatial separation from cattle summer ranges), bison behavior (i.e., thorough cleaning of birth sites), environmental degradation of *Brucella* (i.e., short persistence period in late spring weather conditions), and scavenger removal of potentially infectious birth tissues.

In the Greater Yellowstone Area, bison and elk are infected with *B. abortus* and there can be no guarantee that cattle near Yellowstone's boundaries will not be exposed. Allowing bison to occupy public lands outside the Park for an additional few weeks will help conserve bison migratory behavior and reduce stress on pregnant females and their newborn calves, but this will require active management to minimize the brucellosis transmission risk to cattle. Bison that do not move back into the Park following the calving season in early June should be hazed back inside. At this time, bison should be easier to move and more likely to remain within Yellowstone than in the preceding weeks due to receding snow and vegetation green-up at increasingly higher elevations. Yellowstone bison represent the last wild and free-ranging bison population and their ecological, genetic, and cultural value to facilitate long-term conservation for the species cannot be overstated. We encourage management agencies to consider the information presented here to balance Yellowstone bison conservation with acceptable risk of brucellosis transmission.

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Tables

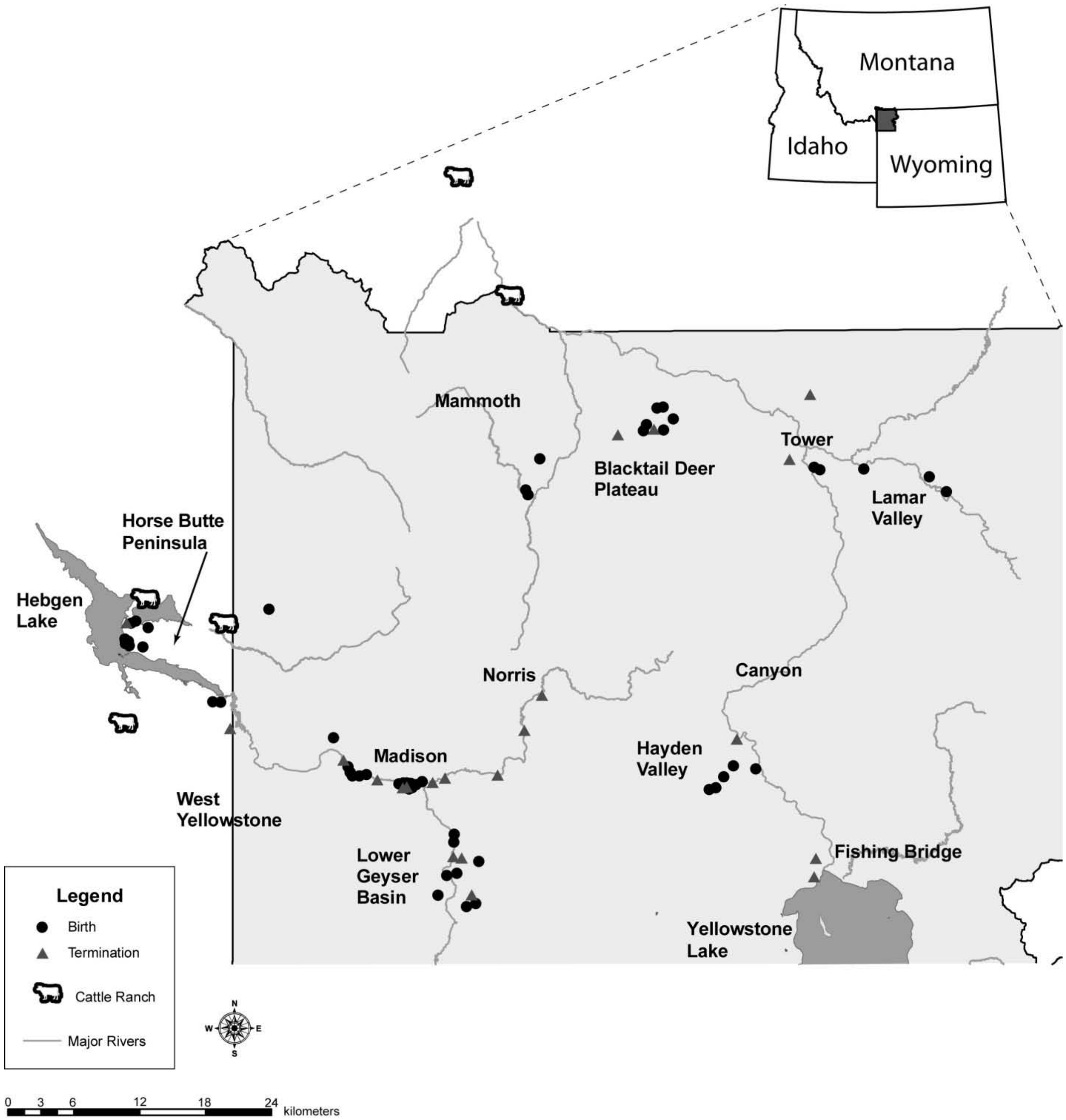
Parturition Event	January	February	March	April (1-15)	April (16-30)	May (1-15)	May (16-31)	June	Event Total
Reproductive failure	1	3	2	7	9	6	1	0	**29**
Live birth	0	0	1	2	13	30	7	1	**54**
Radio-collared bison observed with a calf	0	0	0	0	8	14	10	0	**32**
Time period Total	**1**	**3**	**3**	**9**	**30**	**50**	**18**	**1**	**115**

TABLE 1. Chronology of observed reproductive failures (e.g., abortions, still births), live births, and radio-collared bison observed with a calf in Yellowstone National Park and nearby areas of southwestern Montana during 2004-2007.

Figure Legend

FIGURE 1. Locations of observed reproductive failures (terminations) and live bison births bison in Yellowstone National Park and nearby areas of southwestern Montana during 2004-2007 in relation to cattle operations during winter and spring.

FIGURE 2. Cumulative proportion of observed bison parturition events (live births and reproductive failures) in Yellowstone National Park and nearby areas of southwestern Montana during 2004-2007.


Montana
Idaho
Wyoming
Mammoth
Blacktail Deer Plateau
Tower
Lamar Valley
Horse Butte Peninsula
Hebgen Lake
Norris
Canyon
Madison
Hayden Valley
West Yellowstone
Lower Geyser Basin
Fishing Bridge
Yellowstone Lake
Legend
Birth
Termination
Cattle Ranch
Major Rivers
N
W
E
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0 3 6 12 18 24 kilometers

Figure 1.

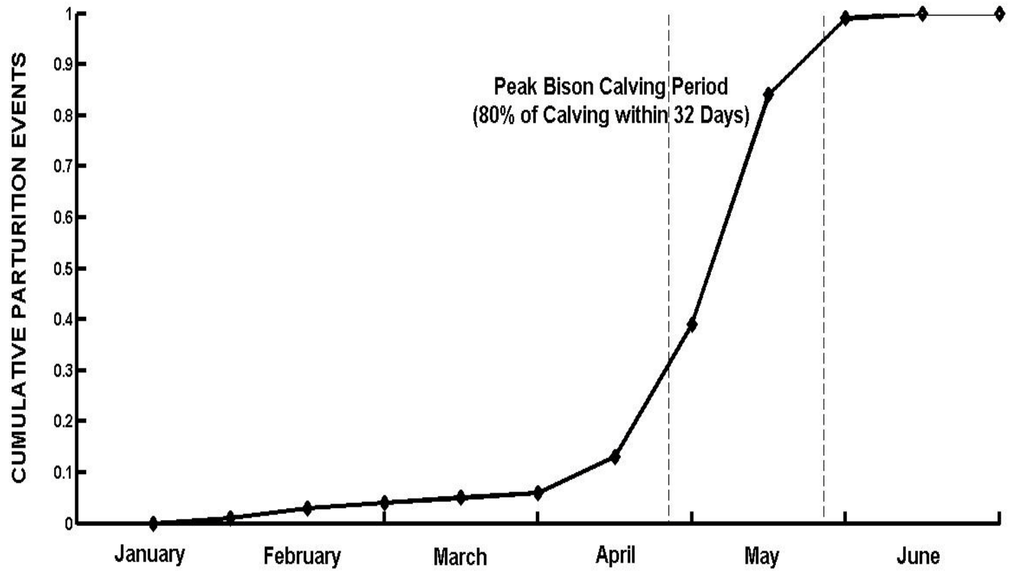
CUMULATIVE PARTURITION EVENTS
Peak Bison Calving Period
(80% of Calving within 32 Days)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
January
February
March
April
May
June

Figure 2.