Does the use of vaginal-implant transmitters affect neonate survival rate of white-tailed deer Odocoileus virginianus

Authors: Swanson, Christopher C., Jenks, Jonathan A., DePerno, Christopher S., Klaver, Robert W., Osborn, Robert G., et al.

Source: Wildlife Biology, 14(2) : 272-279

Published By: Nordic Board for Wildlife Research

URL: https://doi.org/10.2981/0909-6396(2008)14[272:DTUOVT]2.0.CO;2

Does the use of vaginal-implant transmitters affect neonate survival rate of white-tailed deer *Odocoileus virginianus*?

Christopher C. Swanson, Jonathan A. Jenks, Christopher S. DePerno, Robert W. Klaver, Robert G. Osborn & Jeannine A. Tardiff

Swanson, C.C., Jenks, J.A., DePerno, C.S., Klaver, R.W., Osborn, R.G. & Tardiff, J.A. 2008: Does the use of vaginal-implant transmitters affect neonate survival rate of white-tailed deer *Odocoileus virginianus*? - Wildl. Biol. 14: 272-279.

We compared survival of neonate white-tailed deer *Odocoileus virginianus* captured using vaginal-implant transmitters (VITs) and traditional ground searches to determine if capture method affects neonate survival. During winter 2003, 14 adult female radio-collared deer were fitted with VITs to aid in the spring capture of neonates; neonates were captured using VITs (N = 14) and traditional ground searches (N = 7). Of the VITs, seven (50%) resulted in the location of birth sites and the capture of 14 neonates. However, seven (50%) VITs were prematurely expelled prior to parturition. Predation accounted for seven neonate mortalities, and of these, five were neonates captured using VITs. During summer 2003, survival for neonates captured using VITs one, two, and three months post capture was 0.76 (SE = 0.05; N = 14), 0.64 (SE = 0.07; N = 11) and 0.64 (SE = 0.08; N = 9), respectively. Neonate survival one, two and three months post capture for neonates captured using ground searches was 0.71 (SE = 0.11; N = 7), 0.71 (SE = 0.15; N = 5) and 0.71 (SE = 0.15; N = 5), respectively. Although 71% of neonates that died were captured < 24 hours after birth using VITs, survival did not differ between capture methods. Therefore, use of VITs to capture neonate white-tailed deer did not influence neonate survival. VITs enabled us to capture neonates in dense habitats which would have been difficult to locate using traditional ground searches.

Key words: neonate, Odocoileus virginianus, predation, survival, vaginal-implant transmitter, white-tailed deer

Christopher C. Swanson & Jonathan A. Jenks, Department of Wildlife and Fisheries Sciences, South Dakota State University, Brookings, South Dakota 57007, USA - e-mail addresses: christopher.swanson@sdstate.edu (Christopher C. Swanson); jonathan.jenks@sdstate.edu (Jonathan A. Jenks)

Christopher S. DePerno, Robert G. Osborn** & Jeannine A. Tardiff ***, Farmland Wildlife Populations and Research Unit, Minnesota Department of Natural Resources, Rte. 1, Box 181, Madelia, Minnesota 56062, USA - e-mail addresses: chris_deperno@ncsu.edu (Christopher S. DePerno); bob@haydenwing.com (Robert G. Osborn); jtardiff@state.pa.us (Jeannine A. Tardiff)*

Robert W. Klaver, U.S. Geological Survey Center for Earth Resources Observation and Science, 47914 252nd St., Sioux Falls, South Dakota 57198, USA - e-mail: bklaver@usgs.gov

Present addresses:
**Department of Forestry and Environmental Resources, Fisheries and Wildlife Sciences Program, North Carolina State University, Turner House, Box 7646, Raleigh, North Carolina 27695, USA*
***Hayden-Wing Associates, Environmental Consultants, 2308 South Eighth St., Laramie, Wyoming 82070, USA*
****Pennsylvania Game Commission, Ligonier, Pennsylvania 15658, USA*

Corresponding author: Christopher C. Swanson

Received 31 July 2006, accepted 27 February 2007

Associate Editor: Jon M. Arnemo

Neonate survival is affected by predation (Nelson & Woolf 1987, Kunkel & Mech 1994, Benzon 1998, Ballard et al. 1999, Brinkman et al. 2004a, Swanson 2005), disease (Schulz 1982, Brinkman et al 2004b), maternal age (Ozoga & Verme 1986, Kunkel & Mech 1994), and condition of the dam (Porath 1980). In addition, survival of research animals may be affected by capture and marking activities (Hamlin et al. 1982). Capture techniques that minimize disturbance to females and neonates are needed to decrease the probability of capture-related mortality (White et al. 1972). Furthermore, studies should evaluate the indirect effects that marking techniques may have on survival (e.g. predation, starvation and disease) to validate their use (Murray & Fuller 2000).

Although female behaviour is a useful technique for finding neonate deer (Downing & McGinnes 1969, White et al. 1972, Garner et al. 1976, Huegel et al. 1985), capturing neonates in areas with dense cover may be difficult. However, vaginal-implant transmitters (VITs; Bowman & Jacobsen 1998, Carstensen et al. 2003, Johnstone-Yellin et al. 2006) expelled from females at parturition allow researchers to locate birth sites of neonates (Garrott & Bartmann 1984) independent of habitat characteristics (Bowman & Jacobson 1998). Furthermore, VITs allow researchers to sample newborn animals that may typically be missed (Seward et al. 2005).

Garrott & Bartmann (1984), Bowman & Jacobson (1998), Carstensen et al. (2003) and Johnstone-Yellin et al. (2006) used VITs with varying success. Their studies focused on efficacy of VITs to capture neonate deer but did not evaluate impact of VITs on neonate survival. Our objective was to compare survival rates of neonate white-tailed deer *Odocoileus virginianus* captured using VITs and traditional (i.e. nocturnal and diurnal) ground searches to determine if neonate survival was affected by capture method. We hypothesized that the use of VITs would not affect neonate survival.

Study area

Southwest Minnesota (43°29'N to 45°16'N - 093°38'W to 096°27'W) is characterized by flat to rolling topography with elevation ranging within 229-608 m a.s.l. (Albert 1995). As a result of the Wisconsin Glaciation (10,000-100,000 years ago), lobes of glacial ice shaped the landscape in this region (Minnesota River Basin Data Center 2003) creating steeper topography along the Minnesota River and its tributaries (Voigtlander 1999) than in upland prairie habitats. Our study area covered

34,627 km^2 of the farmland region in Minnesota (Swanson 2005).

Tall and mixed prairie grasses (6.5%) accounted for the majority of native vegetation in southwest Minnesota. Of these, big bluestem *Andropogon geradii*, little bluestem *Schizachyrium scoparium*, Indiangrass *Sorghastrum nutans*, switchgrass *Panicum virgatum*, tall dropseed *Sporobolus asper*, and sideoats grama *Bouteloua curtipendula* characterized uplands (Johnson & Larson 1999, Voigtlander 1999). In low wet areas, prairie cordgrass *Spartina pectinata*, reedgrass *Calamagrostis arundinacea*, and sedges (Cyperaceae) were common (Voigtlander 1999). Forested areas (3.0%) were dominated by bur oak *Quercus macrocarpa*, basswood *Tilia americana*, green ash *Fraxinus pennsylvanica*, and eastern cottonwood *Populus deltoides* (Minnesota Association of Soil and Water Conservation Districts Forestry Committee 1986).

Methods

During January-February 2003, we captured female white-tailed deer using helicopter net-guns (Barrett et al. 1982). We immobilized captured deer with ketamine hydrochloride (5 mg/kg IM; Ketaset®; Fort Dodge Laboratories, Fort Dodge, Iowa, USA) and xylazine hydrochloride (1 mg/kg IM; Xylaject®, Phoenix Pharmaceutical Inc., St. Joseph, Missouri, USA) prior to transport (Mech et al. 1985, Kreeger et al. 2002). Adult female white-tailed deer were radio-collared (Advanced Telemetry System, Isanti, Minnesota USA), aged, ear-tagged, measured (chest and neck circumference), and given a broad spectrum antibiotic, after which they were fitted with VITs (N = 14; Advanced Telemetry System, Isanti, Minnesota, USA). Each VIT had a unique frequency and was equipped with a temperature activated sensor that doubled in pulse rate when expelled from the female (Bowman & Jacobson 1998). To reduce vulvar trauma, ends of the antenna were covered with plastic and placed approximately 1-2 cm outside the vulva (Carstensen et al. 2003). Following Mech et al. (1985), we reversed chemical immobilizations using yohimbine hydrochloride (0.125 mg/kg IV; Yobine®, Ben Venue Laboratories, Inc., Bedford, Ohio, USA).

During May-June 2003, neonates were captured and radio-collared during traditional ground searches in Redwood and Renville counties, Minnesota (Swanson 2005). Nocturnal searches were conducted with spotlights from vehicles on roads near potential fawning areas by 2-person teams. Neonates were located by observing behavioural changes exhibited by postpartum females (Downing & McGinnes 1969, Huegel et al. 1985, Benzon 1998). When a neonate was sighted or if the female's behaviour was suspect, a fast, noisy, approach was made to attempt to invoke the 'drop' response of neonates (Downing & McGinnes 1969). Neonates able to run were pursued on foot and captured using long-handled landing nets (Frabill Inc., Jackson, Wisconsin, USA). Ground searches were systematically conducted if an observed adult female remained in the vicinity after being flushed or used vocalizations (e.g. snorting) indicating the possible presence of a neonate (Lund 1975). Additionally, diurnal ground searches (Lund 1975) were conducted in probable fawning habitats using multiple-person crews (i.e. 3-8 people). Crews searched potential fawning areas in a linearly-spaced format looking for hiding neonates or solitary females.

Beginning in mid-May 2003, we monitored VIT signals three times daily (i.e. every eight hours) using a vehicle-mounted radiotelemetry antenna system equipped with a military grade compass (Brinkman et al. 2002, Brinkman 2003) to determine location of birth sites (area with vegetation consumed by female and evidence of afterbirth or neonate present) and to capture neonates. When the temperature activated switch indicated an implant had been expelled, we located the transmitter using hand-held telemetry and secured neonates for processing. If neonates were not immediately located at the birth site, a 300-m radius area surrounding the VIT and the location of radio-collared females was searched (Carstensen et al. 2003). Expelled VITs were located regardless of time of day to reduce chance of neonates moving away from birth sites.

Captured neonates were handled for an average of 4.7 minutes, during which sex, age and weight were recorded. Neonates were aged based on hoof growth measurements (Haugen & Speake 1958, Brinkman et al. 2004c), placed in a drawstring sac that had been stored in natural vegetation to reduce scent contamination and weighed using a digital hanging scale (Extech Instruments, Melrose, Massachusetts, USA). Neonates were fitted with radio-collars (Advanced Telemetry Systems, Isanti, Minnesota, USA and Telonics Inc., Mesa, Arizona, USA) designed to expand and break away six months post capture. To reduce scent contamination, radio-collars were stored in natural vegetation common to searched habitats. Additionally, vinyl gloves were worn by all crew members involved with capture to minimize transfer of human scent. A Global Positioning System (Garmin International Inc., Olathe, Kansas, USA) was used to record capture locations.

Radio-collared neonates were monitored for survival 1-3 times daily until three months of age. When radio-collars remained motionless for four hours, a motion sensitive mortality switch activated doubling the pulse rate of the radio-collar, indicating a potential mortality. Field necropsies were conducted at the site of death and <24 hours from a previous live signal. Evidence of predators (e.g. tracks, scat, hair or carcass burial) along with condition of carcass was examined. When cause of neonate death was not identifiable at the death site, the carcass was sent for further testing to the Animal Disease and Diagnostic Lab at South Dakota State University. Mortalities caused by coyote *Canis latrans* or domestic dog *Canis familiaris* were considered canid predation based on evidence at the death site. All field methods complied with animal care and use guidelines of the American Society of Mammalogists (1998) and the study was approved by the Animal Care and Use Committee (approval number: 02-A043) at South Dakota State University.

We used the Kaplan-Meier method (Kaplan & Meier 1958) modified for staggered entry (Pollock et al. 1989) to calculate monthly survival rates from June through August 2003. Survival estimates were compared between neonates captured using VITs and traditional searches using Program CONTRAST (Hines & Sauer 1989). We conducted t-tests (alpha set at $P \leq 0.05$) to determine if retention of VITs was influenced by deer weight or chest girth. Also, we used t-tests to test for differences in age and handling time between capture methods and χ^2 tests to determine if the percentage of neonates that died differed between capture methods. A Bonferroni correction factor was used to maintain alpha when multiple χ^2 tests or t-tests were performed. We censored neonates if collars failed or prematurely dropped off neonates. Sibling neonates captured at the same birth site via VITs were considered to be independent in the survival analysis because neonates were usually located >0.4 km apart one week post capture.

Results

We fitted 14 adult females with VITs and seven of the implants (50%) were recovered at birth sites, leading to the capture of 14 neonates; two sets of

Table 1. Capture and mortality data of neonate white-tailed deer captured using traditional ground searches and vaginal-implant transmitters in Redwood and Renville counties, Minnesota during spring 2003.

Sex	Capture date	Capture weight (kg)	Handling time (minutes)	Estimated age (±3 days)	Capture Method	Neonate status three months post capture
♂	5/20/03	2.27	6	2	Traditional	Predation
♀	5/20/03	3.85	10	7	Traditional	Alive
♂	5/22/03	2.40	9	1	Traditional	Predation
♂	5/24/03	3.04	4	<1	Implant	Alive
♀	5/24/03	2.77	3	<1	Implant	Alive
♀	5/24/03	2.77	3	<1	Implant	Predation
♂	5/25/03	4.54	6	6	Traditional	Alive
♀	5/25/03	4.40	4	3	Implant	Alive
♂	5/26/03	3.23	7	5	Traditional	Alive
♀	5/27/03	2.80	4	<1	Implant	Predation
♀	5/27/03	2.78	3	<1	Implant	Alive
♂	5/29/03	3.86	4	<1	Implant	Alive
♂	5/29/03	3.90	4	<1	Implant	Alive
♂	5/29/03	3.68	2	<1	Implant	Predation
♂	5/29/03	5.05	3	10	Traditional	Alive
♀	5/30/03	5.48	3	11	Traditional	Alive
♀	5/31/03	3.80	5	<1	Implant	Alive
♂	6/1/03	4.13	3	<1	Implant	Alive
♀	6/1/03	3.69	2	<1	Implant	Predation
♀	6/3/03	3.40	3	<1	Implant	Predation
♀	6/3/03	3.63	4	<1	Implant	Alive

triplets, three sets of twins, and two single neonates. During 20 May-3 June 2003, we captured and radio-collared 21 neonates (14 from VITs and seven from traditional ground searches; 10 males and 11 females) in Redwood and Renville counties, Minnesota. Mean date of birth was 25 May (SE = 1.3; range: 13 May-3 June). Mean neonate age averaged < 1 and 6 days (range: 2-11) for neonates captured via VITs and traditional ground searches (Table 1), respectively. Age at capture differed (t = 3.182, df = 7, P = 0.015) between neonates captured using VITs versus those captured via traditional ground searches (see Table 1). However, age at death did not differ (t = 1.538, df = 5, P = 0.185) between capture techniques. During summer 2003, survival of neonates captured using VITs one, two and three months post capture was 0.76 (SE = 0.05, N = 14), 0.64 (SE = 0.07, N = 11) and 0.64 (SE = 0.08, N = 9), respectively. Neonate survival one, two and three months post capture for neonates captured using traditional ground searches was 0.71 (SE = 0.11, N = 7), 0.71 (SE = 0.15, N = 5) and 0.71 (SE = 0.15, N = 5), respectively. Survival did not differ one month ($\chi^2{}_1 = 0.349$, P = 0.554), two months ($\chi^2{}_1 = 0.186$, P = 0.666) or three months ($\chi^2{}_1 = 0.177$, P = 0.674) post capture for neonates captured using VITs compared to those captured using traditional ground searches. Canid predation accounted for all (N = 7) neonate mortalities during the first three months post capture (see Table 1). Canids killed five of seven (71%) neonates captured via VITs. However, the percentage of neonates that died did not differ between capture methods ($\chi^2{}_1 = 0.107$, P = 0.743). Further, capture weight (see Table 1) of neonates did not differ (t = 0.911, df = 19, P = 0.374) by capture method. Additionally, neonates captured using VITs that died did not differ (t = 1.628, df = 17, P = 0.122) in weight at capture from those that survived. Neonates captured using traditional ground searches were handled longer (t = 3.700, df = 19, P = 0.002) than neonates captured using VITs (see Table 1). However, handling time did not differ (t = 1.826, df = 17, P = 0.086) between neonates that died and were captured using VITs versus neonates that survived. During our study, no instances of abandonment occurred.

Adult female white-tailed deer that expelled implants prior to parturition had average weight and chest girths of 67.1 kg (SE = 1.4) and 103.9 cm (SE = 1.7), respectively. For deer that maintained VITs until parturition, average weight and chest girth was 67.8 kg (SE = 1.3) and 104.7 cm (SE = 1.8), respectively. We did not detect any differences in deer weight (t = 0.361, df = 12, P = 0.724) or chest girth (t = 0.361, df = 12, P = 0.724) for deer that prematurely expelled VITs versus those that maintained VITs until parturition.

We estimated the cost per neonate between capture methods. Cost to deploy one VIT used to capture neonates was $1176.19. The cost included $400 to capture each adult female (N = 14) by helicopter net-gun (Barrett et al. 1982), $200 for each adult radio-collar (N = 14), $25 for immobilizing drugs (Ketamine, Xylazine and Yohimbine) for each adult captured (N = 14), $200 for each VIT (N = 14), $10/hour/person (N = 10) cost during eight hours' adult capture (during winter), $400 lodging expense, + $10/hour/person (N = 1) cost during 81 hours' neonate capture and locating expelled VITs (during spring) + $106.60 for 209.3 liters of fuel to monitor for expelled implants, $200 for neonate radio-collars (N = 14), and miscellaneous equipment (e.g. nets, scales and calipers). Cost to capture one neonate using traditional ground searches was $702.86. The cost included $200 for neonate radio-collars (N = 7), $10/hour/person (N = 2) cost during 116 hours' neonate capture (during spring), + $800 lodging expense, $400 for 757.1 liters of fuel to search for neonates during traditional ground searches, and miscellaneous equipment (e.g. spotlights, scales and calipers).

Discussion

During summer 2003, all documented neonate mortalities (N = 7) were attributed to canid predation, which accounted for 36 and 29% of mortality of neonates captured using VITs and ground searches, respectively. Berger et al. (2001) suggested that a lack of vigilance and failure to detect dangerous predators may contribute to mortality in regions where young are primary targets of predation. During our study, specific measurements and observations of neonates were conducted at birth sites. This disturbance could have weakened the female-neonate bond because of the association with danger at the birth site. Complete isolation is necessary during parturition for proper female-neonate bonding (Ozoga et al. 1982), and disturbance during the first hours of life may weaken this bond. Similarly, Cook et al. (1971) suggested that neonates may eventually die due to the breakdown of female-neonate bonds when a disturbance occurs during the first two days of life. As there was no difference in survival between capture methods during our study, disturbance to the female-neonate bond was not affected by our activities at the birth site.

Neonates captured using traditional ground searches were handled longer than neonates captured using VITs (see Table 1). Similar to the results of Carstensen Powell et al. (2005) and White et al. (1972) handling time did not influence neonate survival. Age at capture differed between capture methods (see Table 1), whereas neonate age at death did not. Neonates captured using VITs survived as long as neonates captured using traditional ground searches and had no apparent survival disadvantage three months post capture. Furthermore, neonates captured using VITs did not seem to have any physiological disadvantages, as capture weight did not differ between capture methods (see Table 1). Weight at capture may have been similar between capture methods due to the condition of the female and the variability of neonate weight at birth. Additionally, neonates that died and were captured using VITs did not differ in weight at time of capture from neonates that survived. Because there was no significant difference in weight at capture between methods, we would expect that survival was not affected by the use of VITs.

Of the predated neonates captured using VITs, 60% died within one month post capture. Similarly, Carstensen Powell et al. (2005) documented high neonate mortality in animals captured within 24 hours of birth. It could be possible that some females react differently to disturbances within the first 24 hours after birth. However, we did not document any negative impact to neonate survival because of the disturbance associated with radio-collaring neonates captured using VITs at the birth site.

Using the predictive equation for adult female weights provided by Weckerly et al. (1987), we calculated an average live weight at capture for adult female deer fitted with VITs of 63.7 kg. Although this weight is slightly lower than that of deer (69.3 kg) captured by Brinkman (2003), we considered these deer to be in excellent condition. Therefore, based on the physical condition of the adult females and the results of other researchers (Bowman & Jacobson 1998 and Carstensen et al. 2003), we did not suspect any reproductive problems associated with using VITs. However, 50% ($N = 7$) of VITs were prematurely expelled prior to parturition. Rate of premature expulsion (50%) was higher than documented by Carstensen et al. (2003; 11%) and Bowman & Jacobsen (1998; 31%). Seward et al. (2005) suggested that implants in elk *Cervus elaphus* can be prematurely expelled by early contractions, stillborn passage (Andersen & Linnell 1998), or an extruding antenna being pulled out by the animal. Because we could not determine if adult females that prematurely expelled VITs continued pregnancy to successful parturition, we were unable to document reproductive problems that may have been caused by VITs. Nevertheless, no VITs were retained past the parturition season.

Because cost is important when planning research (Conner et al. 1987), researchers must utilize efficient techniques that meet desired goals. During our study, the monetary investment of capturing neonates with VITs was approximately \$473 higher per neonate than capturing with traditional ground searches. However, we required 151 less person hours to capture twice the number of neonates during spring neonate capture using VITs compared to traditional searches. Furthermore, we used approximately 552.7 fewer liters of fuel to monitor VITs versus traditional searches to capture neonates. We realize that the cost to capture adult females for the benefit of capturing neonates using VITs is high. However, there are economic benefits to deploying VITs when research objectives include monitoring adult females. Specifically, when adults are factored into the overall cost per adult female/VIT, the cost to capture neonates using VITs was approximately \$115 less expensive than capturing neonates using traditional searches.

Conclusions

During our study, the use of VITs to find and capture neonates did not affect their survival. Although, the majority (71%) of neonates that died were captured using VITs, this disparity was due to chance. We realize that our sample size of neonates was low, and that this may have had an influence on the outcomes of our statistical tests. Nevertheless, our findings are generally supportive of other studies that employed VITs to locate neonate cervids. Future research is needed to determine if the effects of radio-collaring adult females and implanting VITs during pregnancy is an effective tool for safely capturing neonates. Our results indicate that VITs are a means to study neonate white-tailed deer when other capture methods are not practical. VITs allowed for the capture of single to multiple (N = 2 or 3) neonates within hours of parturition. Capturing neonates immediately following parturition ensures the detection of all mortality sources that may otherwise be unknown using traditional capture methods. Researchers must evaluate the success of similar studies to determine if the cost per animal is beneficial using VITs compared to traditional capture methods (Seward et al. 2005). Nevertheless, when capture of neonates is difficult using female behaviour (Downing & McGinnes 1969, Huegel et al. 1985, Benzon 1998) via random searches, VITs could provide the only means for capturing neonates and locating birth sites that would otherwise be missed in dense habitats.

Acknowledgements - funding for this study was provided by Minnesota Department of Natural Resources, South Dakota State University, Bend of the River Chapter of Minnesota Deer Hunters Association, Bluffland Whitetails Association, Cottonwood County Game and Fish League, Des Moines Valley Chapter of Minnesota Deer Hunters Association, Minnesota Bowhunters, Inc., Minnesota Deer Hunters Association, Minnesota State Archery Association I, North Country Bowhunters Chapter of Safari Club International, Rum River Chapter of Minnesota Deer Hunters Association, South Metro Chapter of Minnesota Deer Hunters Association, and Whitetail Institute of North America. In addition, we would like to thank all technicians (J. Smith, C. Schultz) and volunteers that assisted during the capture. We thank K.C. Jensen and B.S. Haroldson for comments on an earlier draft of this manuscript. Any mention of trade, product or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

References

Albert, D.A. 1995: Regional landscape ecosystems of Michigan, Minnesota, and Wisconsin: a working map and classification. - General Technical Report, NC-178, St. Paul, Minnesota, United States Department of Agriculture, Forest Service, North Central Forest Experiment Station, Northern Prairie Wildlife Research Center Home Page. Available at: http://www.npwrc.usgs.gov/resource/1998/rlandscp/rlandscp.htm (accessed 17 February 2005).

American Society of Mammalogists 1998: Guidelines for the capture, handling and care of mammals. - The American Society of Mammalogists, Animal Care and Use Committee, 47 pp. Available at: www.mammalsociety.org/committees/index.asp (accessed 24 September 2002).

Andersen, R. & Linnell, J.D.C. 1998: Ecological correlates of mortality of roe deer fawns in a predator-free environment. - Canadian Journal of Zoology 76: 1217-1225.

Ballard, W.B., Whitlaw, H.A., Young, S.J., Jenkins, R.A. & Forbes, G.J. 1999: Predation and survival of white-tailed deer fawns in northcentral New Brunswick. - Journal of Wildlife Management 63: 574-579.

Barrett, M.W., Nolan, J.W. & Roy, L.D. 1982: Evaluation of hand-held net-gun to capture large mammals. - Wildlife Society Bulletin 10: 108-114.

Berger, J., Swenson, J.E. & Persson, I. 2001: Recolonizing carnivores and naïve prey: conservation lessons from Pleistocene extinctions. - Science 291: 1036-1039.

Benzon, T. 1998: Mortality and habitat use of white-tailed deer fawns in the central Black Hills, South Dakota 1994-1998. - South Dakota Department of Game, Fish and Parks, Pittman-Robertson Game Report W-75-R-34 Pierre, South Dakota, USA, 43 pp.

Bowman, J.L. & Jacobson, H.A. 1998: An improved vaginal-implant transmitter for locating white-tailed deer birth sites and fawns. - Wildlife Society Bulletin 26: 295-298.

Brinkman, T.J. 2003: Movement and mortality of white-tailed deer in southwest Minnesota. - M.Sc. thesis, South Dakota State University, Brookings, South Dakota, USA, 135 pp.

Brinkman, T.J., DePerno, C.S., Jenks, J.A., Haroldson, B.S. & Erb, J.D. 2002: A vehicle-mounted radiotelemetry antenna system design. - Wildlife Society Bulletin 30: 256-258.

Brinkman, T.J., Jenks, J.A., DePerno, C.S., Haroldson, B.S. & Osborn, R.G. 2004a: Survival of white-tailed deer in an intensively farmed region of Minnesota. - Wildlife Society Bulletin 32: 726-731.

Brinkman, T.J., Jenks, J.A., DePerno, C.S. & Haroldson, B.S. 2004b: Clostridium perfringes Type A in a free-ranging fawn? - The Prairie Naturalist 36: 181-186.

Brinkman, T.J., Monteith, K.L., Jenks, J.A. & DePerno, C.S. 2004c: Predicting neonatal age of white-tailed deer in the Northern Great Plains. - The Prairie Naturalist 36: 75-81.

Carstensen, M., DelGuidice, G.D. & Sampson, B.A. 2003: Using doe behavior and vaginal-implant transmitters to capture neonate white-tailed deer in north-central Minnesota. - Wildlife Society Bulletin 31: 634-641.

Carstensen Powell, M., DelGuidice, G.D. & Sampson, B.A. 2005: Low risk of marking-induced abandonment in free-ranging white-tailed deer neonates. - Wildlife Society Bulletin 33: 643-655.

Conner, M.C., Soutiere, E.C. & Lancia, R.A. 1987: Drop-netting deer: costs and incidence of capture myopathy. - Wildlife Society Bulletin 15: 434-438.

Cook, R.S., White, M., Tainer, D.O. & Glazener, W.C. 1971: Mortality of young white-tailed deer fawns in south Texas. - Journal of Wildlife Management 35: 47-56.

Downing, R.L. & McGinnes, B.S. 1969: Capturing and marking white-tailed deer fawns. - Journal of Wildlife Management 33: 711-714.

Garner, G.W., Morrison, J.A. & Lewis, J.C. 1976: Mortality of white-tailed deer fawns in the Wichita Mountains, Oklahoma. - Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 30: 493-506.

Garrott, R.A. & Bartmann, R.M. 1984: Evaluation of vaginal-implants for mule deer. - Journal of Wildlife Management 48: 646-648.

Hamlin, K.L., Mackie, R.J., Mundinger, J.G. & Pac, D.F. 1982: Effect of capture and marking on fawn production in deer. - Journal of Wildlife Management 46: 1086-1089.

Haugen, A.O. & Speake, D.W. 1958: Determining age of young white-tailed deer. - Journal of Wildlife Management 48: 489-499.

Hines, J.E. & Sauer, J.R. 1989: Program CONTRAST-A general program for analysis of several survival or recovery rate estimates. - United States Fish and Wildlife Service, Fish and Wildlife Technical Report 25, Washington D.C., USA, 7 pp.

Huegel, C.N., Dahlgren, R.B. & Gladfelter, H.L. 1985: Use of doe behavior to capture white-tailed deer fawns. - Wildlife Society Bulletin 13: 287-289.

Johnson, J.A. & Larson, G.E. 1999: Grassland plants of South Dakota and the Northern Great Plains. - South Dakota State University College of Agriculture and Biological Sciences South Dakota Agricultural Experiment Station, Brookings, South Dakota, USA, 288 pp.

Johnstone-Yellin, T.L., Shipley, L.A. & Woodrow, L.M. 2006: Effectiveness of vaginal implant transmitters for locating neonatal mule deer fawns. - Wildlife Society Bulletin 34: 338-344.

Kaplan, E.L. & Meier, P. 1958: Nonparametric estimation from incomplete observations. - Journal of the American Statistics Association 53: 457-481.

Kreeger, T.J., Arnemo, J.M. & Raath, J.P. 2002: Handbook of wildlife chemical immobilization. International edition. - Wildlife Pharmaceuticals, Inc., Fort Collins, Colorado, USA, 412 pp.

Kunkel, K.E. & Mech, L.D. 1994: Wolf and bear predation on white-tailed deer fawns in northeastern Minnesota. - Canadian Journal of Zoology 72: 1557-1565.

Lund, R.C. 1975: The capture and marking of wild, newborn white-tailed deer fawns. - Transactions of the Northeast Section of The Wildlife Society 32: 25-33.

Mech, L.D., DelGuidice, G.D., Karns, P.D. & Seal, U.S. 1985: Yohimbine hydrochloride as an antagonist to xylazine hydrochloride-ketamine hydrochloride immobilization of white-tailed deer. - Journal of Wildlife Diseases 21: 404-410.

Minnesota Association of Soil and Water Conservation Districts Forestry Committee 1986: Minnesota tree handbook. - Adventure Publications, Staples, Minnesota, USA, 408 pp.

Minnesota River Basin Data Center 2003: Basin fast facts. - Available at:http://mrbdc.mnsu.edu (accessed 17 February 2005).

Murray, D.L. & Fuller, M.R. 2000: A critical review of the effects of marking. - In: Boitani, L. & Fuller, T.K. (Eds.); Research Techniques in animal ecology: controversies and consequences. Columbia University Press, USA, pp. 15-64.

Nelson, T.A. & Woolf, A. 1987: Mortality of white-tailed deer fawns in southern Illinois. - Journal of Wildlife Management 51: 326-329.

Ozoga, J.J. & Verme, L.J. 1986: Relation of maternal age to fawn-rearing success in white-tailed deer. - Journal of Mammalogy 63: 695-696.

Ozoga, J.J., Verme, L.J. & Bienz, C.S. 1982: Parturition behavior and territoriality in white-tailed deer: impact on neonatal mortality. - Journal of Wildlife Management 46: 1-11.

Pollock, K.H., Winterstein, S.R., Bunck, C.M. & Curtis, P.D. 1989: Survival analysis in telemetry studies: the staggered entry design. - Journal of Wildlife Management 53: 7-15.

Porath, W.R. 1980: Fawn mortality estimates in farmland deer range. - In: Hine, R. & Nehls, S. (Eds); White-tailed deer population management in the north central states. North Central Section of The Wildlife Society, USA, pp. 55-63.

Schulz, J.H. 1982: Mortality and movements of white-tailed deer (Odocoileus virginianus) fawns in southeastern Minnesota. - M.Sc. thesis, Mankato State University, Mankato, Minnesota, USA, 56 pp.

Seward, N.W., Maehr, D.S., Gassett, J.W., Cox, J.J. & Larkin, J.L. 2005: From the field: field searches versus vaginal implant transmitters for locating elk calves. - Wildlife Society Bulletin 33: 751-755.

Swanson, C.C. 2005: Movement and association of white-tailed deer in southwest Minnesota. - M.Sc. thesis, South Dakota State University, Brookings, South Dakota, USA, 117 pp.

Voigtlander, A.L. 1999: Soil survey of Renville County, Minnesota, USA. - United States Department of Agriculture, Natural Resources Conservation Service, 129 pp.

Weckerly, F.W., Leberg, P.L. & Van Den Bussche, R.A. 1987: Variation of weight and chest girth in white-tailed deer. - Journal of Wildlife Management 51: 334-337.

White, M., Knowlton, F.F. & Glazener, W.C. 1972: Effects of dam-newborn fawn behavior on capture and mortality. - Journal of Wildlife Management 36: 897-906.