Survival and Cause-specific Mortality of Adult Male White-tailed Deer Managed Under the Quality Deer Management Paradigm

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Abstract: Quality deer management (QDM) advocates the protection of younger-age white-tailed deer (*Odocoileus virginianus*) bucks, but the subsequent survival of these animals remains unknown. We conducted a study to investigate the impact and importance of harvest and non-harvest mortality factors on adult male white-tailed deer in Mississippi on areas managed under QDM. We captured 408 deer and fitted 238 adult bucks with radio collars from February 1990 until January 1997. During the study, we documented 185 mortalities, which were used to estimate survival and cause-specific mortality rates. Harvest-related and natural mortality accounted for 75% and 12% of buck losses, respectively. Annual survival rates ranged from 0.50 to 0.82 and differed among age classes. Seasonal survival rates ranged from 0.48 to 1.0, with survival during February-September greater than during October-January. Seasonal survival rates did not differ for 1.5-year-old bucks but were different among seasons for 2.5, 3.5, 4.5, and ≥5.5-year-old age classes. Natural mortality rates ranged from 0.02 to 0.15 and differed among age classes. The 1.5- and ≥5.5-year-old bucks had the lowest and highest natural mortality rate, respectively. Hunting mortality ranged from 0.16 to 0.44 and was different among age classes. Males in the <2.5-year age classes had relatively high harvest rates on areas where they were supposed to be protected by selective harvest criteria (i.e., antler restrictions). QDM is an effective management technique for protecting <2.5-year-old bucks. Our research demonstrated if <2.5-year-old bucks are passed up that they will be available for harvest during the next season because these bucks have very little natural mortality.

Key words: cause-specific mortality, harvest, Mississippi, *Odocoileus virginianus*, quality deer management, survival, white-tailed deer

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Quality deer management (QDM) has been a common management paradigm for landowners seeking to improve the quality (i.e., body condition) of their white-tailed deer (*Odocoileus virginianus*) herds. Hamilton et al. (1995:7) defined QDM as "the voluntary use of restraint in the harvesting of young bucks combined with appropriate antlerless deer harvest to maintain a healthy deer population in balance with the habitat." The main objectives of QDM are to harvest sufficient antlerless deer to maintain the population below the carrying capacity of the habitat and to protect the young males (<2.5 years old) so they mature and attain their genetic potential for antler development. An assumption of QDM is that bucks not harvested by a hunter will survive until the next year. With many landowners and hunting clubs engaging in a QDM program, biologists need a better understanding of survival and cause-specific mortality rates of bucks managed under the QDM paradigm.

The management of hunter harvest on a white-tailed deer population requires an understanding of the collective effects of harvest and non-harvest mortality on a population (Dusek et al. 1989, Fuller 1990, Van Deelen et al. 1997). Hunter harvest has been well documented and has been shown to be the most significant cause of mortality for most white-tailed deer populations (Gavin et al. 1984, Halls 1984, Nelson and Mech 1986, Fuller 1990). Although non-harvest mortality usually accounts for little of the annual mortality, it may be a more significant cause of mortality on areas practicing QDM, because older aged bucks may have higher rates of natural mortality and perish before they can be harvested.

However, for QDM to be successful, an unharvested buck must

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survive until the following hunting season. Two possible hypotheses for why bucks may not survive on QDM management areas are: 1) individuals are harvested on adjacent properties not practicing QDM or 2) individuals die from non-harvest mortality factors. Few studies have focused on obtaining reliable rates for non-harvest mortality factors on areas practicing QDM. This study examined the significance of harvest and non-harvest mortality on adult white-tailed bucks in Mississippi on areas practicing QDM. Our objectives were to determine cause-specific mortality of deceased bucks, and compare survival and cause-specific mortality rates among age classes and seasons.

Study Areas

We captured and monitored adult (>1.5 years old) male white-tailed deer on 19 study areas in Mississippi that practiced QDM. Study areas ranged from 607 to 12,140 ha, and were located in 15 different counties (Fig. 1). We had 10 study areas on private hunting clubs in the Delta physiographic region of Mississippi: Ashbrook Island Land Company (2,023 ha), Black Bayou Land and Timber Company (2,630 ha), Caulk Island (3,237 ha), Catfish Point Hunting Club (3,440 ha), Davis Island (12,140 ha), Jackson Point (4,047 ha), Kings Point Island (7,284 ha), Merigold Hunting Club (6,070 ha), Reed Hunting Club (6,070 ha), and Woodstock Hunting Club (2,023 ha). Other study areas were distributed throughout the state (Fig. 1). Mississippi Army Ammunition Plant (1,795 ha) was federally-owned and was the only site restricted to bow-hunting. The remaining eight study areas were privately owned: Cecil Crowe Ranch (1,011 ha), Canemount Plantation (4,168 ha), Camaron Plantation (4,047 ha), Dunlap Property (2,428 ha), Hartwood Plantation (607 ha), Carter Hutchinson Property (1,214 ha), Longleaf Farm (4,047 ha), and Will Clark Property (809 ha). Coggin (1998) provided a detailed description of the habitat and land use of each study area.

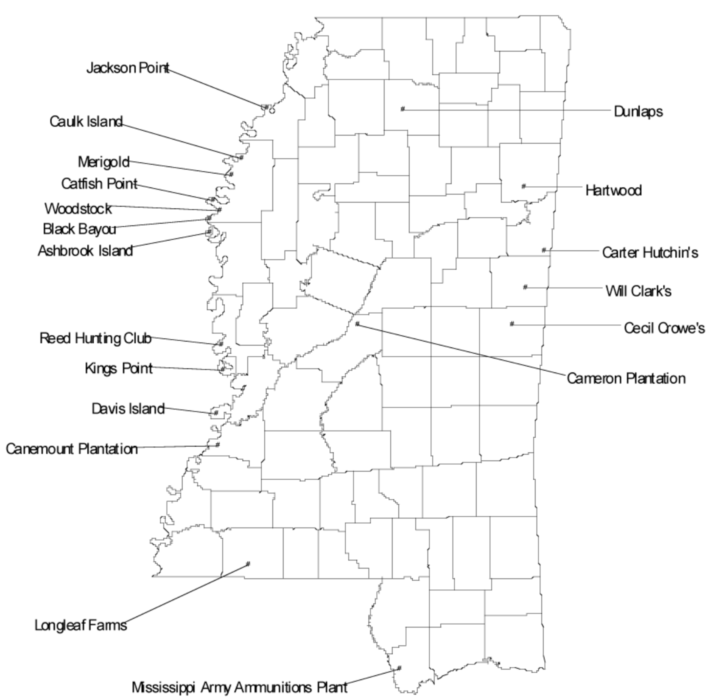

Figure 1. Statewide distribution of study areas for a study investigating adult male white-tailed deer (*Odocoileus virginianus*) mortality in Mississippi, 1990–1997.

Methods

We captured adult bucks (>1.5 years old) on each of the study areas using dartguns with radio-transmitter darts (Palmer Chemical Co., Douglasville, Georgia, and Pneu Dart Inc., Williamsport, Pennsylvania), dropnets (Ramsey 1968), and helicopter netguns (Helicopter Wildlife Management, Salt Lake City, Utah). To immobilize captured bucks, we used a 3:1 mixture of Telazol (3.7 mg/kg) and xylazine-hydrochloride (2.2 mg/kg) in the darts or only xylazine-hydrochloride (2.2 mg/kg) for bucks captured using dropnets. We used yohimbine (0.22 mg/kg) as an antagonist for xylazine-hydrochloride. We manually restrained bucks captured with helicopter netguns. To monitor captured bucks, we fitted them with a radio collar equipped with a 12-hour mortality sensor (Advanced Telemetry Systems, Isanti, Minnesota). Collars were approximately 64 cm in length and 8 cm wide and weighed 868–882 g. Collared individuals also received a metal numbered ear tag (8.5 x 1 mm) with a contact address and phone number. We aged (i.e., 1.5, 2.5, 3.5, 4.5, ≥5.5 years) captured bucks by tooth replacement and wear (Severinghaus 1949, Jacobson and Reiner 1989) and body characteristics (Demarais et al. 1999). Although using tooth wear and replacement to age white-tailed deer is a subject of debate (e.g., Jacobson and Reiner 1989, Van Deelen et al. 2000, Gee et al. 2002), these studies only considered the reliability of aging of mandibles removed from the deer. Because we were able to use a combination of tooth wear and replacement and body characteristics, we believe that we were able to accurately age our captured animals. Additionally, we recorded antler measurements (number of points, tine lengths, main beam lengths, inside spread, and beam circumferences), chest girth, heart rate, respiration, and recal temperature. Bucks also received an injection of LA-200 (Liquamycin) antibiotic (0.05 mg/kg), and we treated all cuts or abrasions with FURALL (Furazolidone) antibacterial spray. The Mississippi State University Institutional Animal Care and Use Committee (Protocol Number 90-006) approved the capturing and handling procedures for this study.

We monitored buck survival from a ground vehicle or fixed-winged aircraft every 2–4 weeks. When a mortality signal was detected, we conducted an immediate search to find the buck and determine cause of death. We classified mortalities as legal harvest, illegal harvest, wounding loss, unknown harvest, natural, unknown natural, unknown, vehicle, capture, or collar related. For bucks taken by legal means during the hunting season (1 October–31 January), we classified them as legal harvest. We classified mortalities known or believed to be poached (e.g., cut or mutilated collars found near roads) as illegal harvest. Bucks shot and not retrieved due to delayed mortality or the inability of the hunter to find the deer were classified as wounding loss. We classified mortalities in which the animal was shot but the legality of the shot was uncertain as harvest unknown. Mortalities caused by disease, parasites, or predation were classified as natural mortality. We classified mortalities not caused by humans, but where the exact cause (e.g., disease, trauma, or predator) of mortality was uncertain, as natural unknown. Mortalities that we could not determine the cause of mortality were classified as unknown mortalities. We classified mortalities caused by a collision with a vehicle as vehicle mortality. Capture-related mortality was for bucks that experienced capture myopathy (Beringer et al. 1996) or succumbed to known injuries within 12 days following capture. Collar mortality described those mortalities that can be linked to the collar (e.g., infection, wound related to collar presence, or leg caught in collar).

We estimated annual survival and mortality rates for harvest and natural causes by age classes. Due to small sample sizes in some cause-specific categories, we combined all harvest-related mortalities (i.e., legal harvest, illegal harvest, wounding loss, and harvest unknowns) into a hunting category. Also, we combined all natural causes (i.e., natural and natural unknown) into a natural category. For all other mortality causes (vehicle and unknown), we combined them into an other category. We omitted capture and collar mortalities from our analyses because these represented researcher-induced events. To examine differences in mortality rates among seasons, we partitioned the year into three periods of biological significance to white-tailed deer bucks: post-rut (February–May), summer (June–September), and hunting season (October–January). For annual calculations, we began the year on 1 August when the population was at or near its yearly peak (i.e., after most fawning was complete). For reporting sample sizes and analyses, we considered each buck a different individual as it progressed from one age class to another.

We estimated survival and cause-specific mortality rates using MICROMORT (Heisey and Fuller 1985), and compared these rates for collared bucks using program CONTRAST (Hines and Sauer 1989). Program CONTRAST tested for differences ($\alpha = 0.05$) in annual and seasonal survival and cause-specific mortality among age classes and years using a z-test. When the overall test was rejected, pairwise *z*-tests were performed that were Bonferonni corrected (i.e., $\alpha = 0.013$ age class comparisons). In addition, we tested for differences in survival rates among seasons for each age class.

Results

From February 1990 until January 1997, we captured 408 deer and fitted 238 adult bucks with radio-collars. We captured 103 (43%), 92 (39%), 32 (13%), 7 (3%), and 4 (2%) bucks in the 1.5, 2.5, 3.5, 4.5, and ≥5.5-year-old age classes, respectively. Because we counted a buck as a different individual as it progressed from one age class to another, our sample size for each respective age class was 94, 143, 105, 63, 49 bucks. We documented 185 mortalities during the seven years of our study. Harvest-related deaths, natural mortality, and other mortality causes accounted for 138 (75%), 23 (12%), and 6 (3%) mortalities, respectively (Table 1). We excluded 18 (10%) mortalities from our survival analyses because these mortalities were a consequence of capture-related mortality.

Annual Survival

Annual survival rates ranged from 0.44 to 0.82 for the five age classes (Table 2) and differed among age classes ($\chi^2_4 = 41.72$, $P < 0.001$). Survival rates for 1.5-year-old bucks were greater than 2.5-year-old bucks ($\chi^2_1 = 8.37$, $P = 0.004$), but similar among 2.5, 3.5, 4.5, and ≥5.5-year-old bucks ($P > 0.013$). Annual survival rates did not differ among years for any age class ($P \geq 0.118$).

Seasonal Survival

Seasonal survival rates ranged from 0.48 to 1.00 (Table 2). Bucks had greater survival rates during February–May and June–September for all ages than during October–January (Table 2). Survival rates for February–May differed among age classes ($\chi^2_4 = 12.63$, $P = 0.013$). Rates for 1.5 and 2.5-year-old bucks during this period

Table 1. Summary of mortalities by age class for adult white-tailed deer (*Odocoileus virginianus*) bucks in Mississippi, 1990–1997.

Mortality cause	1.5-year-old	2.5-year-old	3.5-year-old	4.5-year-old	≥5.5-year-old	Total
Legal harvest	9	29	31	26	12	107 (58%)
Illegal harvest	0	1	4	4	3	12 (6.5%)
Wounding loss	2	2	2	0	1	7 (4%)
Harvest unknown	0	4	7	0	1	12 (6.5%)
Natural	1	2	4	2	4	13 (7%)
Natural unknown	0	2	1	4	3	10 (5%)
Unknown	0	2	1	1	1	5 (3%)
Vehicle	0	0	0	0	1	1 (<1%)
Capture	10	2	1	0	1	14 (8%)
Collar	0	1	1	2	0	4 (2%)
Total	22 (12%)	45 (24%)	52 (28%)	39 (21%)	27 (15%)	185

Table 2. Survival and cause-specific mortality rates among age classes of adult white-tailed deer (*Odocoileus virginianus*) bucks in Mississippi, 1990–1997.

						Cause-specific mortality rate					
				Survival		Hunting[a]		Natural[b]		Other[c]	
Age class (year)	Interval	*n*	Radio-days	Rate	SE	Rate	SE	Rate	SE	Rate	SE
1.5	Annual	94	13,515	0.821	0.002	0.164	0.002	0.015	0.001	0.0000	0.000
	February-May	21	1,752	1.000	0.000	0.000	0.000	0.000	0.000	0.0000	0.000
	June–September	43	4,286	1.000	0.000	0.000	0.000	0.000	0.000	0.0000	0.000
	October–January	86	7,477	0.821	0.002	0.164	0.002	0.015	0.001	0.0000	0.000
2.5	Annual	143	29,436	0.633	0.002	0.297	0.002	0.050	0.001	0.0201	0.001
	February–May	75	7,965	0.970	0.001	0.000	0.000	0.030	0.001	0.0000	0.000
	June–September	88	9,826	0.975	0.001	0.000	0.000	0.012	0.001	0.0123	0.001
	October–January	120	11,645	0.669	0.002	0.314	0.002	0.009	0.001	0.0087	0.001
3.5	Annual	105	27,454	0.533	0.001	0.403	0.001	0.055	0.001	0.0094	0.001
	February–May	79	8,795	0.947	0.001	0.027	0.001	0.027	0.001	0.0000	0.000
	June–September	79	9,218	1.000	0.000	0.000	0.000	0.000	0.000	0.0000	0.000
	October–January	99	9,441	0.563	0.001	0.397	0.001	0.030	0.001	0.0099	0.001
4.5	Annual	63	18,094	0.444	0.004	0.442	0.004	0.099	0.002	0.0146	0.001
	February–May	55	6,292	0.963	0.001	0.019	0.000	0.019	0.001	0.0000	0.000
	June–September	55	6,255	0.962	0.001	0.000	0.000	0.038	0.001	0.0000	0.000
	October–January	53	5,547	0.480	0.004	0.457	0.004	0.047	0.001	0.0158	0.001
≥5.5	Annual	49	15,144	0.499	0.005	0.318	0.004	0.145	0.003	0.0374	0.001
	February–May	51	5,482	0.916	0.002	0.000	0.000	0.084	0.002	0.0000	0.000
	June–September	44	5,307	0.933	0.001	0.000	0.000	0.067	0.001	0.0000	0.000
	October–January	42	4,355	0.584	0.005	0.372	0.005	0.000	0.000	0.0438	0.001

a. Hunting = legal harvest, illegal harvest, wounding loss, and harvest unknowns
b. Natural = natural and natural unknown
c. Other = vehicle and unknown

were greater than older age classes ($\chi^2_1 = 4.32$, $P = 0.038$). We did not detect a difference in survival rates among age classes during June–September ($\chi^2_4 = 0.30$, $P < 0.99$). Survival rates during October–January also differed among age classes ($\chi^2_4 = 34.28$, $P < 0.001$). Survival rates for 1.5-year-old bucks were greater than 2.5-year-old bucks ($\chi^2_1 = 5.61$, $P = 0.018$). Bucks that were 2.5 years old had greater survival than 3.5-year-old bucks ($\chi^2_1 = 5.36$, $P = 0.021$), but survival was similar among 3.5-year-old and older bucks ($\chi^2_2 = 1.72$, $P = 0.424$). Seasonal survival rates did not differ among years for any age class ($P \geq 0.125$) except for ≥5.5-year-old bucks during October–January ($\chi^2_4 = 44.05$, $P < 0.001$). Survival rates did not differ among seasons for 1.5-year-old bucks ($\chi^2_2 < 0.001$, $P > 0.99$) but were different for 2.5 – ($\chi^2_2 = 44.72$, $P < 0.001$), 3.5 – ($\chi^2_2 = 959.31$, $P < 0.001$), 4.5 – ($\chi^2_2 = 56.02$, $P < 0.001$), and ≥5.5-year-old bucks ($\chi^2_2 = 19.68$, $P < 0.001$). In all cases, survival was similar in February–May and June–September but less in October–January.

Cause-specific Mortality

Hunting mortality rates ranged from 0.164 to 0.442 (Table 2) and differed among age classes ($\chi^2_4 = 31.69$, $P < 0.001$). These rates were less for 1.5-year-old bucks than 2.5-year-old bucks ($\chi^2_1 = 4.75$, $P = 0.029$) and less for 2.5-year-old bucks than 3.5-year-old bucks ($\chi^2_1 = 5.91$, $P = 0.015$) but similar among 3.5-year-old and older bucks ($\chi^2_2 = 2.19$, $P = 0.335$). Because hunting mortality occurred almost exclusively during October-January, we did not conduct tests on seasonal differences. The hunting mortality rate did not differ among years for any age class ($P \geq 0.100$) except for ≥5.5-year-old bucks ($\chi^2_4 = 44.26$, $P < 0.001$).

Natural mortality rates ranged from 0.02 to 0.15 (Table 2) and differed among age classes ($\chi^2_4 = 10.25$, $P = 0.036$). Bucks that were 1.5, 2.5, and 3.5 years old had greater survival than 4.5- and ≥5.5-year-old bucks ($\chi^2_1 = 5.73$, $P = 0.017$). Natural mortality rates were different among age classes during February–May ($\chi^2_4 = 10.13$, $P = 0.038$). The 1.5-year-old bucks had the lowest natural mortality rate, the 2.5-, 3.5-, and 4.5-year-old bucks had similar rates, and the ≥5.5-year-old bucks had the greatest natural mortality ($\chi^2_4 = 10.03$, $P = 0.007$). Natural mortality rates were not different among age classes during June–September ($\chi^2_4 = 1.03$, $P = 0.905$) or October–January ($\chi^2_4 = 8.02$, $P = 0.091$). Also, the natural mortality rate did not differ among years for any age class ($P \geq 0.125$) except for ≥5.5-year-old bucks ($\chi^2_4 = 12.05$, $P = 0.017$).

Discussion

We documented a greater annual survival rate for bucks in the younger age classes (1.5–2.5 years) compared to older age class bucks, which suggests that QDM was effective on our study sites. Additionally, survival rates for October–January and hunting mirrored these results, and provided evidence that hunting was the most important cause of mortality. Natural mortality in the younger ages classes (1.5–2.5 years) accounted for <5% of the mortalities, suggesting that if a buck is not harvested, it will survive to the next hunting season. Most yearling males (63%) were legally harvested on the study areas; 37% of yearling harvests occurred off the study areas. Hunters who harvested a yearling male usually mistakenly shot it for a doe. In the 2.5-year-old age class, 60% of the legal harvest occurred off the study areas, which is similar to what others have described where hunting pressure on younger age class males was greater on surrounding areas than on the study area (Hawkins et al. 1971, Kammermeyer and Marchinton 1976, Dozer 1997).

Most high mortality rates for male white-tailed deer have been attributed primarily to hunting (Nelson and Mech 1986, Fuller 1990), with yearling and 2-year-old males being more susceptible to harvest than older bucks (Maguire and Severinghaus 1954, Rosenberry and Klimstra 1974, McCullough 1979, Nelson and Mech 1986). Greater harvest susceptibility of younger bucks likely is related to lack of experience (Dasmann and Taber 1956), dispersal into unfamiliar areas during hunting (Rosenberry and Klimstra 1974, Nelson and Mech 1986), and larger home range size (Webb et al. 2007). The yearling harvest rate (16%) that we documented was less than that observed by Nelson and Mech (1986; 34%), Fuller (1990; 33%) and Nixon et al. (1991; 33%), but was similar to the rate observed by Ditchkoff et al. (2001; 13%) on an area practicing QDM. Dozer (1997) hypothesized that younger males experienced higher non-harvest mortality under a QDM program. However, natural mortality (2%) for the yearling class in our study was similar to the rates observed by Nixon et al. (1991; 5%) and Ditchkoff et al. (2001; 3%). Natural mortality rates >5% have been reported by Nelson and Mech (1986; 20%) and Fuller (1990; 9%) but these rates are from Minnesota where wolf (*Canis lupus*) predation is the primary natural mortality cause. Seasonally, the only sources of mortality for the yearling class occurred during October-January and were limited almost exclusively to hunting.

Several studies have reported similar mortality rates for 1.5-year-old and 2.5-year-old bucks (Nelson and Mech 1986, Nixon et al. 1991, Ditchkoff et al. 2001). The 2.5-year-old harvest rate (30%) that we documented was similar to that observed by Nelson and Mech (1986; 34%) and Nixon et al. (1991; 33%), but was greater than the rates observed by Ditchkoff et al. (2001; 13%) and DeYoung (1989; 7%) on study areas where restrictions were placed on the buck harvest. Under a QDM program, restricting buck harvest is usually done by placing criteria on antler characteristics such as number of points or inside spread (Dozer 1997). The average 2.5-year-old male harvested in our study had 8 points, an inside spread of 33 cm, and main beam lengths of 38 cm (Coggin 1998). These measurements were comparable to the average antler restrictions imposed on most of our study areas and surrounding clubs. Fewer younger bucks were harvested on areas where Ditchkoff et al. (2001) and DeYoung (1989) conducted their research, but their sites may have required stricter antler restrictions or our areas may have had greater harvest pressure. Natural mortality for the 2.5-year-old age class (5%) in our study remained low and was similar to the yearling class and to the rates observed by Nixon et al. (1991; 5%) and Ditchkoff et al. (2001; 3%) but lower than DeYoung (1989; 15%). We observed natural mortalities in all seasons equally in contrast to natural mortality, which only occurred in October-January for the 1.5-year-old age class.

Survival rates reported for older age class bucks (≥3.5 years) have been variable among studies (Nelson and Mech 1981, DeYoung 1989, Nixon et al. 1991, Ditchkoff et al. 2001). The survival rates we documented (44%–53%) were comparable to Nelson and Mech (1981; 47%), but were greater than Nixon et al. (1991; 39%) and less than DeYoung (1989; 74%) and Ditchkoff et al. (2001; 68%). Adult male deer (>2.5) in our study had greater harvest mortality than the 1.5-year-old and 2.5-year-old classes. Of the known harvest locations of males 3.5 years and older, 54% were located on the study areas, which contrasts with Webb et al. (2007) who documented that older bucks had smaller home ranges and were less likely to be harvested off the area. Our lower survival rates and greater harvest rates compared to DeYoung (1989) and Ditchkoff et al. (2001) likely resulted from greater harvest pressure on our study areas and adjacent properties. Caughley (1966) reported that as age increases so does the mortality rate, which was evident for our study. Non-harvest or natural causes claimed a greater proportion of the collared males as they aged. Higher post-rut natural mortality related to rut stress is thought to be a significant cause of mortality in older bucks (Gavin et al. 1984, DeYoung 1989, Heffelfinger 1989, Ditchkoff et al. 2001), but our results showed no clear seasonal trend.

Management Implications

Our results demonstrate that if <2.5-year-old bucks are protected from harvest they will survive to the next hunting season with few losses to natural mortality. A common method for protecting younger age males is antler restrictions (e.g., beam length or inside spread; Strickland and Demarais 2000), because these measurements usually increase as a buck ages and can be judged in field situations (Hamilton et al. 1995). To be effective, antler restrictions should be developed using harvest data from the area because antler characteristics are dependent on the deer genetics and habitat quality in a particular area (Strickland and Demarais 2000). We documented most of the legal harvest locations of <2.5-year-old males occurring off the study areas, so we recommend that efforts be made to recruit adjoining clubs to participate in QDM management by forming cooperatives. Cooperatives can be used to formally develop a white-tailed deer harvest strategy to protect particular sex and age classes (Dozer 1997).

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