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Robert L. Pooler
Cornell University, Ithaca, NY

Paul D. Curtis
Cornell University, Ithaca, NY

Milo E. Richmond
Cornell University, Ithaca, NY

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ROBERT L. POOLER, Department of Natural Resources, Cornell University, Ithaca, NY 14853-3001

PAUL D. CURTIS, Department of Natural Resources, Cornell University, Ithaca, NY 14853-3001

MILO E. RICHMOND, Department of Natural Resources, Cornell University, Ithaca, NY 14853-3001

Abstract: During March 13 - July 16, 1996, we captured 75 white-tailed deer (*Odocoileus virginianus*) using dart guns, rocket nets, and Clover traps on the Seneca Army Depot in Romulus, New York. We compared the labor and cost efficiency of these trapping techniques and reported on mortalities. Darting from a vehicle ($196/deer), and rocket-netting ($172/deer) were similar in time and cost efficiency. Darting from a blind was more costly ($358/deer) due to minimal time devoted to the technique and a high initial material investment. Clover traps were relatively inefficient (15.2 hours/deer) and costly ($895/deer), primarily due to a lack of snow. Materials comprised most of the total cost for all methods. Darting from a vehicle had the highest mortality (9.5%, n=2 of 21). Cost efficiency for all trapping techniques was poorly represented in the literature.

Key Words: capture, Clover trap, dart gun, *Odocoileus virginianus*, rocket netting, trapping, white-tailed deer

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Live capture of white-tailed deer (*Odocoileus virginianus*) can be a costly, time consuming process (Rongstad and McCabe 1984). Boyer and Brown (1988) reported that cost, labor needs, and available funding were the most common reasons state agencies did not live trap and translocate wildlife more frequently. However, as human and deer populations continue to expand, increasing deer-human conflicts dictate the need for live capture of deer for research and management purposes.

Several studies have reported person-hours required for live-deer-removal techniques, yet few have described the cost efficiency breakdown. Six state agencies averaged $142/deer captured and translocated, with costs ranging from $70-$200/deer (Boyer and Brown 1988). Jordan et al. (1995) reported an average of $117/deer over 2 years with Clover traps. Ishmael and Rongstad (1984) reported that a dart gun was their most time efficient technique at 20.5 hours/ deer, whereas the Clover trap was least cost effective at $570/deer. Our objective was to critically examine the time and cost efficiency and reported mortality rates for rocket nets (Hawkins et al. 1968), Clover traps (Clover 1954), and dart guns used to capture 75 white-tailed deer from March 13-July 16, 1996, at Seneca Army Depot (SAD) in Romulus, New York.

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STUDY AREA

The 3,997-ha SAD is located in Seneca County near the Village of Romulus, New York, and was established in 1942 for the storage of munitions. The former farmland site is enclosed by a 2.4-m security fence and contains 79% natural habitat and 21% paved roads, railroads, housing, storage and administrative buildings. The natural habitat consists of 6.4% wetlands, 15% mature woodlots (*Quercus* spp., *Acer* spp., *Tilia americana*, *Carya* spp.), and 78.6% grass or shrub lands, including dense thickets (*Cornus racemosa*) and hundreds of grass-covered, earthen-berm, storage bunkers. The area is dissected by roads and

drainage ditches surrounded by mowed strips that attract deer during spring green-up. Ambient air temperature during captures ranged from -7° to 26° C.

The SAD deer population grew from the original 20-40 deer enclosed within the fence in 1942 to an estimated 2,500-3,000 deer in 1957. Live-trapping removed 318 deer in 1954 and 1955, however, this failed to significantly slow deer population growth (Bromley and Severinhaus 1956). Hunting was first used as a management tool in 1957, and since has been used successfully to maintain deer densities on SAD close to NYSDEC recommendations. Hunters (307) using guns harvested 275 deer during 5 days in fall 1995, whereas 81 bow hunters killed an additional 31 deer from mid-October to mid-November.

METHODS

Live-capture methods employed during March 13-July 16, 1996, included rocket nets, single-gate Clover traps, darting over bait, and darting from a vehicle. Seventy-five deer were captured and translocated 0-14.5 km via pickup truck to the enclosed 263-ha quarantine area (QA) of the SAD. Bait sites were chosen based on safety relative to explosives stored in nearby bunkers, accessibility from roads, and deer travel patterns. Sites were baited with apples, apple pumice, cracked corn, and salt. Trapping and translocation was accomplished by 1 person for 166 out of 215 (77%) trapping occasions. Volunteers (1-5) helped during the remaining 49 occasions. Deer processing included the attachment of numbered, color-coded collars, 21 of which contained solar-powered transmitters (Telemetry Systems Inc., Mequon, Wis.) with motion-sensitive mortality switches, and aluminum ear tags; collecting weights and blood samples; assessing animal condition; and aging deer by noting body size as a fawn (<1 yr.) or adult (≥1 yr.). A leverage system with spring-loaded scales permitted weighing of deer by 1 person. Mortality rate calculations included the number of deer dying at the release site, and the number of radio-collared deer dying within 1 month of release.

Two rocket net set-ups were used from March 22-June 13, 1996. The nets (12.2 x 18.3 m, and 13.1 x 17.4 m, with 15.2 x 15.2-cm nylon mesh) each were launched by 4 rockets mounted on 1.8-m steel rods. Circuit continuity was checked with a blasting ohmmeter and rockets were detonated with a capacitor-discharge blaster from a canvas blind 36-73 m from the bait site. Deer were captured at rocket sites around dawn and dusk. Pure xylazine hydrochloride (Rompun, Miles Laboratories, Shawnee Mission, KS) was administered intramuscularly at 2.2 mg/kg to deer while under the net. The antagonist yohimbine hydrochloride (Yobine, Lloyd Laboratories, Shenandoah, IA) was administered intravenously at 0.11 mg/kg upon release of deer in the QA (Mech et al. 1985).

Modified Clover traps (McCullough 1975) were used from March 13-April 9, 1996. Five, single-gate Clover traps (0.91 x 0.91 x 2.1 m) were set in mowed areas near storage bunkers. Traps were checked 1-2 hours after sunrise each day. Traps were collapsed on deer and drugs administered as in the rocket nets.

Darting with a scoped, Model 193 dart gun (Pneu Dart Inc., Williamsport, Penn.) occurred from a vehicle during March 15-July 16. Between March 16-March 23, and June 12-June 20, darting was conducted from a blind over bait. Disposable 2-cc darts with 1.9-cm needles and gelatin collars injected pure xylazine or a mixture of xylazine, ketamine hydrochloride (Ketaset, Fort Dodge Laboratories, Fort Dodge, IA), and tiletamine and zolazepam hydrochlorides (Telazol, Fort Dodge Labs, Fort Dodge, IA) at 2.2 mg/kg. No antagonist was administered when the Telazol mixture was used. Shots were made from the blind at <35 m at dawn and dusk. While darting from the vehicle, shots ranged from 14-45 m, and involved driving the SAD roads during hours of peak deer activity. After dark, darting was aided by a 1,000,000-candlepower spotlight. To ensure that deer were immobilized, we waited >15 minutes prior to initiating a search, and allocated 1.0-1.5 hours/ search. Capture methods were approved by the Cornell University Institutional Animal Care and Use Committee.

Cost calculations for materials included 2 new dart guns; 2 blinds; 1 rocket net set-up, including charges, drugs, bait; and the cost for renovating 5 Clover traps. These figures did not include 1 borrowed rocket net set-up. No transport crates were needed.

RESULTS

Depending on the capture method used, trapping efficiency varied with small mammal density, habitat type, time of year (availability of alternative foods), weather, individual deer wariness, light conditions, and capture mortality. Seventy-five deer were captured and translocated to the QA; we had an estimated mortality of 5.3% (Table 1). Combining data for all capture methods, time and costs averaged 8.28 hours/deer and $203/deer, respectively. Overall, trapping was most successful from March 13-April 23, when 72% of all deer were captured. Rocket nets and darting from a vehicle had similar labor and cost efficiency whereas Clover traps were most labor intensive (15.2 hrs/deer) and costly ($895/deer), with 1 deer captured in 105 trap nights. Cost of materials accounted for the majority of the total cost for all capture methods (Table 1).

Darting from a vehicle was most influenced by habitat type, light conditions, time of year, and mortality. Deer darted along roads frequently would disappear immediately into thickets, making prolonged visual contact impossible and confounding the recovery process. This resulted in a 43.8% (*n*=21 of 48) recovery rate. Only 34.8% (*n*=8 of 23) of the deer darted after dark were recovered, whereas 52.0% (*n*=13 of 25) darted during daylight were recovered. Darting was most successful (19 of 21 deer captured) immediately after roadside green-up in mid-April. Darting from a vehicle had the highest mortality (9.5%, *n*=2 of 21), with 1 death due to shot placement and the other due to excessive shot penetration in the hindquarters.

Trapping efficiency for rocket nets was influenced most by time of year and availability of alternative foods. Rocket nets were most successful during March 22-April 23, when 83% (*n*=39 of 47) of the deer were captured (for an average of 4.68 hrs/deer and $126/deer). After April 23, spring green-up and the break-up of deer family groups resulted in fewer animals visiting bait and more incidences of single deer visiting the trap sites.

Minimal time was devoted to darting from a blind due to availability of rocket net equipment. All 6 deer successfully darted over bait were captured during March 15-19. Alternative natural food was available during the second period of darting over bait (mid-June), and no deer were caught. The overall recovery rate during March was 85.7% (6 of 7 search attempts). Five of 6 deer darted in daylight were recovered (83.3%), and 1 of 2 were recovered after dark (50%).

Clover-trap success was influenced by small mammal density and weather. Raccoons (*Procyon lotor*), opossums (*Didelphis marsupialis*), and gray squirrels (*Sciurus carolinensis*) frequently set traps off prematurely. The only useable deer captured was trapped immediately after a late-season snow storm. Jordan et al. (1995) and Beringer et al. (1996) also noted the influence of snow on Clover-trap success.

DISCUSSION

Labor Efficiency

Comparisons of labor efficiency for dart-gun, rocket-net, and Clover-trap methods indicated that our time/deer was similar to figures reported elsewhere, while our mortality rate was lower. Hawkins et al. (1967) used 2-person crews during both daylight and dark hours to dart 1 deer from a vehicle every 7.5 hours, with a 20% mortality rate (*n*=75). Palmer et al. (1980) reported 4.1 hrs/deer captured in daylight, with a 13.6% mortality rate (*n*=44). Ishmael and Rongstad (1984) noted that darting from vehicles was their most time-efficient capture technique at 20.5 hrs/deer (*n*=6), and only 2 animals died; no report of trapping crew size or light conditions was provided. The increased mortality rates reported in these studies compared to that at SAD may have been due, in part, to improvements in immobilization drugs, and to a lack of post-release mortality factors (i.e., high vehicle traffic and predators) at SAD, which are thought to affect short-term survival of white-tails (Jones and Witham 1990).

Palmer et al. (1980) used rocket nets with 1-2 people, and reported 6.9 hrs/deer (*n*=17) and a 23.5% mortality rate. Anderson and Stroebe (1973) used 3-4 people, resulting in 21.6 hrs/deer captured (*n*=11). Jones and Witham (1995) averaged 2.83 hrs/deer caught (*n*=24) during 2 days of mid-winter trapping. Beringer et al. (1996) indicated that rocket nets were more efficient than Clover traps at their study site. They noted deer mortality during rocket-net

attempts was 2.6%, whereas loss due to capture myopathy was 11.2%.

Nielson (1982) darted 22 deer over bait without any mortality; however, no hours/deer were reported. Diehl (1988) noted this effort likely was less efficient than Pisgah-Clover traps used during 1985-86 at the same site. Kilpatrick et al. (1996) darted deer during day and night using 3 people and reported an average capture success of 20.5 hrs/deer (*n*=23) and a 52% recovery rate (no mortality was indicated). They were able to reduce average capture time to 4.0 hours/deer (*n*=15) and increase the recovery rate to 100% by using transmitter darts.

Diehl (1988) reported no mortalities and an average of 4.0 hrs/deer captured (*n*=20) using 2-6 people and Pisgah-Clover traps. Ishmael and Rongstad (1984) captured 2 deer in 179 winter trap nights (43.9 hrs/deer) and cited the Clover trap's proximity to unrestricted bait piles as a reason for the inefficiency. Jordan et al. (1995) reported that their Clover traps captured 451 deer in 3,269 trap-nights during 1991-1993. Beringer et al. (1996) had a 5.1% mortality rate from accidents and none from myopathy while capturing 115 deer with Clover traps.

Cost Efficiency

Few reports of cost/deer or cost breakdowns for darting, rocket-netting, or Clover traps were found in the literature. Ishmael and Rongstad (1984) reported $179/deer (*n*=6) while darting from a vehicle; labor (41.8%) and materials (36.8%) comprised most of the total cost ($1,074). Adjusting Ishmael and Rongstad's figures to current (1996) prices increased the cost/deer to $289, and the total cost to $6,274. They also spent $1,424 during rocket netting (including 79% on materials and 13% on labor), but were unsuccessful in capturing a single deer.

No costs/deer were available in the literature for darting over bait, although Diehl (1988) noted that 4 hrs/deer captured in Pisgah-Clover traps represented a significant reduction in time, and therefore money expended/deer, compared with darting over bait for the same area. Kilpatrick et al. (1996) noted costs of darting over bait were reduced when transmitter darts were used over standard darts due to reduced search times/darted deer.

Jordan et al. (1995), using mainly Clover traps, reported an average of $117/deer captured (*n*=292) and a total of $32,245 during 1991-1992. These prices included labor and vehicle operations as the largest expenditures. Ishmael and Rongstad (1984) captured 2 deer in Clover traps at $570/deer ($921/deer in 1996 prices); materials (46.0%) and labor (28.1%) accounted for most of the total cost ($1,139).

Bromley and Severinghaus (1956) reported $28.93/deer (*n*=318) for 12 box traps on the SAD from 1954-1956. The total cost ($9,200) included labor (83.0%), travel (11.0%, including 200 mile transport distance), and materials (6.0%). Adjusting for inflation increases the cost/deer to $169, which is lower than Clover traps ($895/deer) and combined cost/deer ($203) on SAD in 1996. Bromley and Severinghaus adjusted for trap depreciation over time, accounting for decreased material costs, resulting in the lower cost/deer.

All cost estimates for capturing deer during this study at SAD should be considered minimum values. Employing only 1 person, leaving the vehicle parked on site when not in use to reduce travel time, and borrowing some equipment, helped reduce total costs. Our calculations did not include vehicle or equipment depreciation.

With limited funds and labor being a current reality for most wildlife managers and researchers, and with the increasing need to resolve deer-human conflicts, precise planning for the most productive use of available resources is of ever-increasing importance. Comparable reports of cost efficiency can help facilitate this process.

In summary, rocket-netting prior to spring green-up, and darting from a vehicle immediately after spring green-up, were our most cost-efficient deer-trapping methods. A mild winter with minimal snowfall limited the efficacy of Clover traps at SAD. Also, we did not evaluate fully the cost-efficiency of darting from a blind because of increased reliability of capturing deer with rocket-nets at bait sites while snow cover was present.

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Table 1. Cost- and time-efficiency of deer trapping methods used at the Seneca Army Depot, Romulus, New York, during March through July, 1996.

Trapping method	No. deer	Mortality (n)	Person hours/deer	% of Total Cost			Total cost	Cost/ deer
				materials	fuel	labor		
Rocket nets	47	2	8.3	50.4	1.7	47.9	8,092	172
Clover traps	1	0	15.2	78.8	4.3	17.0	895	895
Dart/vehicle	21	2	7.7	56.8	4.2	39.1	4,111	196
Dart/blind	6	0	9.5	72.3	1.3	26.4	2,151	358