Wildlife Session

Oral Biomarking of a Supplementally-fed Herd of Free-ranging White-tailed Deer

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Abstract: A field study was undertaken to: 1) determine if a large number of free-ranging white-tailed deer (*Odocoileus virginianus*) could be marked with tetracycline hydrochloride (THC), and, if successful, 2) assess use of supplemental feed by deer. Shelled corn treated with THC (approximately 300 mg/0.45 kg) was distributed (18 Jul–3 Aug 1992) on a commercial hunting club in South Carolina that supplementally fed white-tailed deer. Mandibles collected from 784 hunter-harvested deer (15 Aug 1992–1 Jan 1993) were evaluated for THC marks. Of those, 67.8% from the club where treated corn was deposited and 29.4% taken on surrounding properties were marked. Marked deer were found throughout the area studied (i.e., up to 5.43 km from nearest treatment site). The recovery of marked deer on and off the hunting club suggested that deer "exchange" occurred. However, because of the shape and juxtaposition of treated and untreated areas it could not be determined whether supplemental feeding was beneficial or detrimental to deer harvests on neighboring management units. This study demonstrated that

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tetracycline can be used to mark large numbers of free-ranging deer and suggests that delivery of oral medications such as parasiticides or vaccines may be feasible.

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Tetracycline has been used as a biomarker to evaluate delivery of oral vaccines (Hanlon et al. 1989, Fletcher et al. 1990) and toxicants (Lindsey et al. 1971, Lefebvre et al. 1985) and to study wildlife movements and population dynamics (Savarie et al. 1992). Research with captive white-tailed deer has demonstrated that a single oral dose of 300 mg of tetracycline produces distinct marks in deer mandibles which persist undiminished over 150 days (Van Brackle et al. 1994). However, a large-scale field effort to biomark a free-ranging deer population has not been reported. The objectives of our study were to: 1) determine if a large number of free-ranging deer could be marked with tetracycline, and, if successful, 2) assess use of supplemental feed by deer harvested throughout the area.

This study was made possible through sponsorship from the fish and wildlife agencies of Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, Missouri, North Carolina, Puerto Rico, South Carolina, Tennessee, Virginia, and West Virginia. Funds for this project were provided by the Federal Aid to Wildlife Restoration Act (50 Statute 917), McIntire-Stennis Project Number GEO-0030-MS-H, and through Grant Agreement #14-16-0004-92-909, Fish and Wildlife Service, United States Department of the Interior. Financial contributions also were provided by the Cedar Knoll Club and Mr. Andrew Harper. Special thanks go to all the persons cooperating in our study, especially the hunters and to personnel of the South Carolina Department of Natural Resources (SCDNR).

Methods

Study Area

The study area was located on and around the Cedar Knoll Club (CKC), an unfenced 1,862-ha commercial hunting club in Allendale County, South Carolina. The area is in the South Atlantic Coastal Plain physiographic province and the habitat has been previously described by Ruth (1990). On CKC, shelled corn was offered *ad libitum* to deer from August through spring greenup in April (Ruth 1990). About 113 kg of corn was maintained on the ground approximately every 20 ha. Hunting over bait is legal, and most deer harvested on CKC are taken with rifles from stands overlooking feeding stations. Maximum harvest without restriction or selection of antlered animals is practiced. Harvest totals on CKC increased exponentially from 4.4/km^2 to 17.6/km^2 between 1985 and 1988, closely paralleling changes in corn consumption over the same period (Ruth 1990). Harvests were relatively stable at around 20 deer/km^2 annually

between 1989 and 1991 and corn use followed a similar trend. Deer physical condition has remained good based on general observations of body weights, antler characteristics, etc.

Habitats on surrounding properties are similar to CKC. These properties are managed utilizing selective buck harvest or traditional deer management; three are commercially operated. Some properties practice low intensity feeding, and focal baiting with corn is common. Stillhunting from stands is the most common harvest method, but a few hunting clubs also conduct dog drives. In general, annual harvests also have increased on the surrounding properties and throughout the county in recent years, mostly from increased doe harvests. Annual harvests average between 5 and 10 deer/km^2 on most areas.

Corn Treatment and Deposition

We placed shelled corn in 227 kg batches in a Sperry New Holland™ Model No. 353 feed mill (New Holland, Pa.) with the hammer-mill disengaged. We lightly sprayed the slowly spinning corn with water to reduce dust. Then, a solution of 150 g tetracycline hydrochloride (THC) and varying amounts of water (3.8–18.9 L) and Rhoplex-B60A® (Rohm and Haas Co., Philadelphia, Pa) (0–3.8 L) was poured slowly over the corn. Rhoplex®, an acrylic polymer, was useful as a binding and water-repelling agent (Lindsey et al. 1971, Van Brackle et al. 1994). The mixture was spun rapidly for 4 minutes to ensure even coating. Samples inspected under a hand-held ultraviolet (UV) light (Model UVL-56, Blak-Ray® Lamp, Ultra-violet Products, Inc., San Gabriel, Calif.) were well coated with THC. The corn amount and THC concentration (approximately 300 mg/0.45 kg of corn) were based on previous captive studies and small-scale feed preference trials (Van Brackle et al. 1994).

THC-treated corn was distributed (18 Jul–3 Aug 1992) at 69 established feeding sites (70–100 kg/site) on 1,660 ha of CKC (Fig. 1) from a truck fitted with a gravity-operated hopper bed. Treated corn was deposited every few days whenever previously deposited corn had been eaten, soured, sprouted, or washed away by rains. Rhoplex® was not included in the treatment applied to 1,360 kg of corn distributed on 3 August.

Data Collection

Mandibles were removed from all deer (N = 454) harvested on CKC during the 1992–93 hunting season; legal hunting seasons were 15 August–1 January for antlered bucks (≥1.5 years old) and 1 October–1 January for antlerless deer. Jaws also were provided from most (N = 330) deer taken on cooperating adjacent properties representing approximately 10,560 ha. Mandibles were refrigerated or frozen prior to submittal and stored at −4 C until examination. Deer harvest locations were plotted on 1:20,000 soil survey maps (Eppinette 1993) and the distance (closest 0.1 km) to the nearest CKC treatment site estimated. Jaws and/or data were not provided from all deer killed on surrounding areas for various reasons (e.g., heads taken intact to taxidermists).

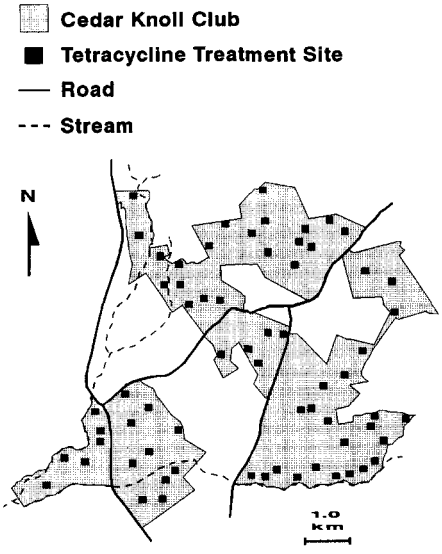

Figure 1. Sites on Cedar Knoll Club where corn treated with tetracycline hydrochloride was deposited from 18 July through 3 August 1992.

Jaws were aged (Severinghaus 1949), scraped clean, and examined for gross surface fluorescence under hand-held UV light (Van Brackle et al. 1994). Undecalcified mandibles were sectioned (100–150 μm thick) transversely anterior to the first premolar and sections were microscopically examined under UV light for THC deposition following Fletcher et al. (1990). CKC jaws displaying substantial gross fluorescence were not sectioned after microscopic examinations confirmed marks in the first 59 grossly positive jaws. All mandibles collected from surrounding properties were sectioned and evaluated under magnification. Fifty mandibles were randomly collected as negative controls from deer killed on Webb Wildlife Center, a SCDNR wildlife management area in Hampton County approximately 30 km from CKC.

Statistical Analyses

For analyses of the percentages of marked deer harvested over the entire hunting season, deer were grouped by sex and by age as adults (≥2.5 years old), yearlings (1.5–<2.5 years old), and fawns (0.5–<1.5 years old). Surrounding properties were considered as 1 area for statistical comparison to CKC.

Because the frequencies of deer harvested did not necessarily reflect probability proportional sampling for each of the effects considered, the data were analyzed using the general linear model (GLM) procedure for least squares analysis of disproportionate subclass frequencies (SAS Inst. 1989) with tests of significance being based on the simultaneous consideration of all effects. Sources of variation in the model for deer ≥1.5 years old included main effects for area, age, and sex and all possible interaction terms. Fawns were analyzed separately from older deer using a model which included main effects for area

and sex and all possible interaction terms. The means reported are the observed percentages marked.

Results

Corn Consumption

Cedar Knoll's feeding season had begun prior to our treatment period. About 6,930 kg of untreated corn were consumed in 9 days prior to treatment. In contrast, during the first 9 days of the treatment period (18–26 Jul) only 3,765 kg of THC-treated corn was consumed. Consumption of treated corn increased to approximately 5,350 kg during the second half of the treatment period (27 Jul–5 Aug). Uptake appeared to increase when 1,360 kg of treatment that did not contain Rhoplex® was offered on 3 August. We assumed most corn was eaten by deer; however, non-target species seen eating treated corn on occasion included wild swine (*Sus scrofa*), wild turkey (*Meleagris gallopavo*), crows (*Corvus* spp.), raccoons (*Procyon lotor*), gray foxes (*Urocyon cinereoargenteus*), gray squirrels (*Sciurus carolinensis*), fox squirrels (*Sciurus nigra*), rabbits (*Sylvilagus* spp.), and numerous songbird species.

Tetracycline Marking

Substantial numbers of harvested deer were marked with THC, both on and off the treated area. Of all deer evaluated, 67.8% ($N = 454$) and 29.1% ($N = 347$) were marked on CKC and surrounding areas, respectively.

The percentages marked of deer sampled from surrounding properties were fairly stable with increasing distance (Table 1), and marked deer were harvested on all portions of the area where mandibles were collected (Fig. 2). The farthest marked deer harvested in the study area were a yearling buck and a yearling doe taken about 5.43 km from the nearest treatment site on CKC.

Both on and off CKC, the percentages of harvested bucks that were marked were highest early in the hunting season. The percentages of does that were marked generally were stable over the hunting season.

A greater ($P = 0.0001$) percentage of deer ≥1.5 years old harvested on CKC (69.1%, $N = 405$, SE = 2.25) were marked than on surrounding areas (30.4%, $N = 300$, SE = 2.62). Although the overall sex effect was not significant ($P = 0.5703$) (Table 2), the effect of area by sex interaction was significant ($P = 0.0269$). Examination of the area by sex means (Table 2) demonstrated a difference in the ratio of marked percentages for harvested bucks and does within each area. Does harvested on CKC were marked 4.1% more often than the bucks, but on surrounding lands, bucks were marked 18.6% more often than does (Table 2).

The effects due to age ($P = 0.0023$) and age by sex ($P = 0.006$) were highly significant and the 3-way interaction among area, sex, and age group had a significance level of $P = 0.0827$. Comparing the percentages of harvested yearlings and adults within sex on each area (Table 3) showed that yearling males

Table 1. Observed percentages of harvested deer by sex and age group that were marked with tetracycline hydrochloride (THC) on Cedar Knoll Club (CKC) and within increasingly distant areas on surrounding properties in Allendale County, South Carolina.

Distance (km) from closest THC treatment site	Bucks						Does					
	Adults		Yearlings		Fawns		Adults		Yearlings		Fawns	
	N	% marked	*N*	% marked	*N*	% marked	*N*	% marked	*N*	% marked	*N*	% marked
0.0 (CKC)	74	75.7	206	65.0	31	61.3	87	64.4	38	89.5	18	50.0
<1.6	16	43.8	43	41.9	8	37.5	60	20.0	13	53.8	12	25.0
1.61–3.2	24	29.2	42	45.2	8	12.5	29	6.9	10	20.0	7	0.0
3.21–4.8	11	9.1	13	38.5	5	40.0	6	16.7	7	14.3	4	25.0
4.81–6.4	4	50.0	5	40.0			2	0.0	1	100.0		

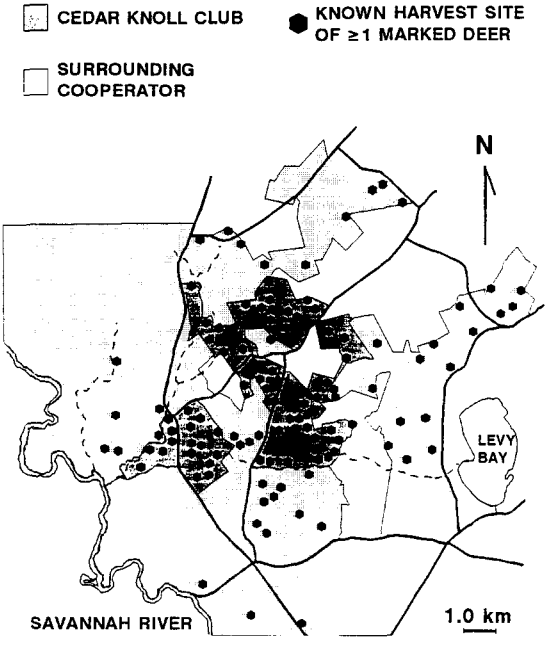

Figure 2. Known locations on Cedar Knoll Club and surrounding properties in Allendale County, South Carolina where deer that were marked with tetracycline hydrochloride were harvested (15 Aug 1992–1 Jan 1993).

Table 2. Total percentages of bucks (≥1.5 yrs old) and does (≥1.5 yrs old) that were marked with tetracycline hydrochloride in harvests on Cedar Knoll Club and surrounding properties in Allendale County, South Carolina.

	Bucks			Does			
Area	*N*	% marked	SE	*N*	% marked	SE	*P*[a]
Cedar Knoll Club	280	67.9	2.71	125	72.0	4.05	0.2223
Surrounding properties	162	38.9	3.56	138	20.3	3.86	0.0595
Areas combined	442	57.2	2.15	263	44.9	2.79	0.5703

[a]Statistical tests were based on least squares analysis for disproportionate subclass frequencies. However, observed means (i.e., % marked) are reported.

on CKC were marked 10.7% less often than the adult bucks, but on surrounding areas, yearling bucks were marked 13.0% more often than the adult bucks. Among harvested does, yearlings were marked 25.1% and 21.2% more often than adults on CKC and surrounding properties, respectively (Table 3).

The percentage of harvested fawns that were marked also was greater ($P = 0.0006$) on CKC (57.1%, $N = 49$, SE = 6.6) than on surrounding properties (21.3%, $N = 47$, SE = 6.74). The percentages of harvested fawns that were marked did not differ ($P > 0.4$) between the sexes on either area, and area and sex did not interact ($P = 0.9227$).

Table 3. Comparisons between adults (≥2.5 yrs old) and yearlings (1.5 yrs old) of the percentages of deer that were marked with tetracycline hydrochloride in the harvests on Cedar Knoll Club and surrounding properties, Allendale County, South Carolina.

	Cedar Knoll Club						Surrounding properties					
	Bucks			Does			Bucks			Does		
Age group	*N*	% marked	SE	*N*	% marked	SE	*N*	% marked	SE	*N*	% marked	SE
Yearlings	206	65.0	3.16	38	89.5	7.35	106	43.4	4.4	33	36.4	7.89
Adults	74	75.7	5.27	87	64.4	4.86	56	30.4	6.05	105	15.2	4.42
P^a		0.0839			0.0045			0.0819			0.0197	

[a]Statistical tests were based on least squares analysis for disproportionate subclass frequencies. However, observed means (i.e., % marked) are reported.

None of the 50 control mandibles collected from deer harvested at Webb Wildlife Center 30 km from CKC demonstrated any evidence of tetracycline marking.

Discussion

The initial decrease in treated corn consumption was most likely a result of deer aversion to THC as has been reported by Van Brackle et al. (1994). Deer may become more tolerant of THC over time, which could explain the subsequent increase in use on CKC; however, the deletion of Rhoplex® from the last treatment confounds this observation.

We assume that differences in percentages of marked deer among sex and age groups, locations, and times resulted from differences in corn use, THC uptake in bone, deer movement, harvest vulnerability, or any combination of these factors, as opposed to loss of THC marks. It was not surprising that a higher percentage of bucks than does taken from surrounding areas would be marked. Bucks generally have larger ranges and move more than does (Marchinton and Hirth 1984) and would have been more likely to have wandered onto CKC to encounter treated corn or have moved from CKC to be harvested elsewhere. The higher percentages marked of yearling does relative to adult does may have been reflective of age-related differences in treated corn use and/or harvest susceptibility.

During the first 2 weeks of hunting (bucks only), over 90% of the deer that were harvested on CKC and 60% of those from surrounding properties were marked. The subsequent declines as the season progressed suggested that deer killed first may have been those most acclimated to corn and, thus, more susceptible to hunting over bait as speculated by Lewis (1990). Other explanations for the decline are movements of unmarked bucks into or marked bucks out of the study area. Unlike bucks, the percentages of marked does in the harvests generally were stable over the season. Perhaps if they had been harvested as early and as continuously as males, their marked percentages also would have declined.

The disjunct sections and irregular boundaries of CKC dictated that the ranges of many deer would have included both CKC and surrounding areas. Based on Marchinton and Hirth's (1984) discussion of deer movements, it is probably inappropriate to consider harvested deer as originating from and being "exchanged" between 2 discrete herds. Therefore, our results could not clearly demonstrate whether CKC's supplemental feeding program positively or negatively affected the deer harvest on surrounding areas. In future studies, the use of 2 different marking agents on the 2 parts of a study area may be helpful in addressing this problem.

Research and Management Implications

The ability to deliver a biomarker to significant numbers of free-ranging deer has many implications for studies involving deer movement, longevity, or

food or mineral use. This work demonstrated that tetracycline is an effective biomarker for free-ranging white-tailed deer. The materials were not expensive, and large sample sizes can be obtained if jaws are available from hunter-killed deer or road-kills. Refinement of the technique should be explored to maximize effectiveness. It may be possible to deliver the biomarker through other mediums (e.g., mineral licks or commercially-prepared feeds) which may provide more flexibility in project design.

Regarding health management, our results show that delivery of oral treatments, such as parasiticides (Qureshi et al. 1989, Garris et al. 1991) or potential vaccines (Nettles 1992), to significant portions of free-ranging deer herds may be feasible. The harvest of marked deer on surrounding properties suggests that treatments could be applied in a relatively localized area and still be delivered to individuals over a much larger area. Achieving and maintaining 100% treatment over time on unfenced properties would be unlikely because of various reasons, including deer movements, mortality, and natality.

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