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Journal
Proceedings of the Vertebrate Pest Conference, 27(27)

ISSN
0507-6773

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Publication Date
2016

DOI
10.5070/V427110348

Influence of Visual Input on Behavior of White-tailed Deer (*Odocoileus virginianus*) to an Auditory Alert Recording

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ABSTRACT: The objective of this study was to determine the importance of visual verification in the behavioral response of white-tailed deer to an auditory alert recording. We utilized a portable, remote-controlled sound system to play recordings of the white-tailed deer alert "blow." In Phase I, the sound treatment was administered from a single location in a 1.3-ha grass lawn surrounded by wooded areas and roads with limited visibility, to free-ranging white-tailed deer on the Berry College campus during day and night hours. In Phase II, sound treatments were administered from varying locations in open lawn and hay fields. Recordings of deer activity were obtained from a digital camcorder and a FLIR thermal imagery camera. Behavior of white-tailed deer in response to the audio recording was classified as Passive (no altered behavior), Alert (actively observing and/or listening toward the recorded sound), Active (slow to moderate intentional movement toward or away from the recorded sound), or Flight (running away from the recorded sound). Six 10-sec periods of activity were evaluated. The pretreatment period (Pre Treat) began one minute prior to activation of the alert sound. The next four time periods [Sound (T1-T3)] represent the four consecutive 10-sec time frames from initiation of the sound treatment. A post-treatment (Post Trt) period was approximately 60 sec following the T3 period. In both phases, deer exhibited decreased Passive Behavior and increased Alert Behavior and Active Behavior following administration of the sound treatment. In the more confined area (Phase I) at night, deer tended to exhibit Alert and Active Behaviors longer than during the day. In the more open areas (Phase II), the degree of Active Behavior was diminished, with deer in the day tending to seek out the location of the sound. The results indicate that the use of visual verification to the auditory alert influenced behavioral response of white-tailed deer, and may be more critical in the areas where that process is limited compared to more open landscapes.

KEY WORDS: behavior, bioacoustic alert, hazing, *Odocoileus virginianus*, white-tailed deer

Proc. 27th Vertebr. Pest Conf. (R. M. Timm and R. A. Baldwin, Eds.)
Published at Univ. of Calif., Davis. 2016. Pp. 384-389.

INTRODUCTION

The white-tailed deer (*Odocoileus virginianus*) may cause more damage than any other species of wildlife in the United States (VerCauteren et al. 2006). While significant work has been reported in the use of audio stimuli as a repellent for many avian species, efforts to utilize sound as a repellent for deer is limited (Seamans et al. 2013). In order for any acoustic-based repellent to potentially have an effect, the animal must be capable of hearing and responding to that sound. Using various methodologies, the hearing of white-tailed deer has been reported to range from 0.115 kHz to 54 kHz with greatest sensitivities in the 4-8 kHz region (D'Angelo et al. 2007, Heffner and Heffner 2010, Biondi et al. 2011, DeVault et al. 2011).

Efforts to utilize auditory stimuli as a deterrent typically fall into broad categories of ultrasonic, sonic, or bioacoustic (Seamans et al. 2013). Ultrasonic sound is generally considered to be frequencies of ≥20 kHz and typically consists of a human-made sound. While being within the reported hearing range, the use of a high frequency sound (25 kHz) was not effective in repelling deer from roadways (Valitzski et al. 2009). Sonic sound frequencies typically encompass the hearing range with the greatest sensitivities for a target species. Examples of sonic auditory deterrents used for deer including propane cannons (Belant et al. 1996, Gilsdorf et al. 2004) or sirens (Gilsdorf et al. 2004) were reported to have limited or short-term effectiveness of no more than one-two weeks. Bioacoustic sounds are represented as alert, alarm or distress calls produced by a specific species (Seamans et al. 2013). Gilsdorf et al. (2004) utilizing a device emitting the recording of a deer in distress had limited effectiveness when utilized in corn fields. In a later study, the same distress recording was determined to be effective in minimizing consumption of available feed (Hildreth et al. 2013). It has been proposed that the device may be more effective in areas that have less protective cover for the deer (Gilsdorf et al. 2004).

Habituation is likely the biggest challenge related to the limited effectiveness of auditory repellents (Craven and Hygnstrom 1996, Nolte 1999). Without some type of negative reinforcement, animals become less wary over time (Nolte 1999). It has been proposed that devices that incorporate sight and sound may delay habituation (Belant et al. 1996, Nolte 1999).

The objective of this study was to determine the importance of visual verification in the behavioral response of white-tailed deer (*Odocoileus virginianus*) to an auditory alert recording. We speculated that response of deer to an auditory alert call is highly influenced by the ability to visually determine if an immediate threat exists.

STUDY AREA

We conducted our study on the 1,215-ha Berry College Wildlife Refuge (BCWR) within the 11,340-ha Berry College campus in northwestern Georgia, USA. The BCWR was within the Ridge and Valley physiographic province with elevations ranging from 172 m to 518 m (Hodler and Schretter 1986). The BCWR was characterized by campus-related buildings and facilities for the student body of 2,200, interspersed with expansive lawn, hay fields, pastures, woodlots, and larger forested tracts. Forested areas were dominated by pines (*Pinus* spp.), oaks (*Quercus* spp.), and hickories (*Carya* spp.). The areas used for this study were characterized as a transition zone from campus lawn to agricultural hayfields. Lawn areas consisting of orchard grass (*Dactylis glomerata*), fescue (*Schedonorus phoenix*), and white clover (*Trifolium repens*) extended from buildings used for housing approximately 100 m into hayfields predominantly composed of Bermuda grass (*Cynodon dactylon*).

During Phase I of the experiment, the test site consisted of an approximately 1.3-ha lawn area bordered by an asphalt parking lot, paved two-lane road, and forested areas. In the second phase (Phase II) of the experiment, 56 ha of contiguous hayfields and lawn was divided into 12 potential test areas based on physical structures including forest borders, roads, buildings, and visible topography. Each test area ranged from 1.3-12.2 ha.

The BCWR had a deer population estimated at 25 deer/km^2 (D. Booke, Georgia Dept. of Natural Resources, pers. comm.). Due to significant contact with humans and lack of hunting pressure, deer on the college campus are highly habituated to the presence of humans.

METHODS

We constructed a portable, remote-control bioacoustics device capable of administering the sound treatment from a distance of 0.4 km. An electronic sound board was modified from a bioacoustics deer repellent product (Deer Shield Pro, Bird Gard, LLC, Sisters, OR). Audio recordings of the common white-tailed deer alert "blow" from three different deer were also provided by Bird Gard. The sound board was mounted in a water proof plastic container and attached to one end of the top of a plastic toolbox (Husky #17330788, Home Depot, Atlanta, GA). An outdoor speaker, rated by the manufacturer to operate at 0.5-5 kHz (Bird Gard LLC), was attached to the other end of the top of the tool box. The speaker was connected to the electronic sound board.

A 12-v battery (Super Star-U1LUH, East Penn Mfg. Lyon, PA) required to operate the sound system was placed within the tool box. A double-pole, double-throw knife switch (SB24049M, Nasco, Salida, CA) was mounted on plywood (20 × 15 × 1 cm). Electrical wiring connecting the power supply to the switch and electronic sound board was attached. A remote control servo (Futaba, Model S3152, Futaba Corp. of America, Schaumburg, IL) and radio receiver (Tactics TR 625, Hobbico Inc., Champaign, IL) were also attached to the plywood. Space was provided to allow connection of a 1,600-mAh battery pack (DTXM2012, Duratrax, Champaign, IL) to operate the remote control receiver and servo. A single piece of 12-ga steel wire was configured and attached between the knife switch and the remote control servo in such a manner that the circuit connecting the electronic sound board to the power supply could be activated (lowering the knife switch) or deactivated (raising the knife switch), via the remote control system transmitter (Tactic TT X650, Hobbico Inc.). The battery pack utilized to operate the servo and radio receiver was replaced daily to ensure available power for treatment applications.

Data Collection

A digital camcorder (Handycam DCR-SX63, SONY Corp. of America, New York, NY) was utilized to obtain day recordings between 0700-1100 h. Digital recordings obtained during the night were obtained using a FLIR thermal imaging camera (FLIR, B200, Wilsonville, OR) and recorded onto a laptop computer (GD6000, General Dynamics ITRONIX, Spokane Park, WA) via a video transfer device (VC500, Diamond Multimedia, Conoga Park, CA.) between 1900-2300 h.

In order to administer the sound treatment, a minimum of three mature deer were required to be within 100 m of the bioacoustics device and in the field of view of the cameras recording activity. Recording of digital images was conducted at a distance of at least 100 m from the bioacoustics device. Recordings were obtained for approximately five minutes. Approximately two minutes of recording occurred prior to administration of the sound treatment. The 15-sec sound treatment consisted of three individual deer expressing 3-4 "alarm blows" each. Digital image recordings were then obtained for an additional three minutes.

Animal use procedures were approved by the Berry College Institution Animal Care and Use Committee (IACUC No - 2013-14-013).

Phase I

The bioacoustics device was placed in understory brush on the edge of forested area within a 1.3-ha experimental site. At least some components of the device including the speaker could be seen from the lawn area. The device remained in the same location throughout this phase of the experiment. Sound treatment administration and digital recordings were obtained between the dates of 6-18 October 2015 during the day (n = 10) and night (n = 5). Moon phases during this time period ranged from a waxing crescent, to a new moon, to a waning crescent. Thus, additional light available at night as a result of light reflection on the moon was minimal.

Phase II

During Phase II, 56 ha of contiguous lawn and hayfields including the Phase I location, were divided into 12 areas based on geographical/topographical boundaries such as roads, forested edges, and campus buildings. For both day and night treatment times, once a group of deer were identified, the bioacoustics device was transported and placed in a non-visible location along a defined border of that specific area. Digital recordings were obtained by setting up the recording equipment at an opposite border of the same area. Thus, deer were located between the bioacoustics device and the recording equipment. In all cases, recordings were obtained at a distance >100 m from the deer. Deer were typically within 100 m from the bioacoustics device. Following filming a group of deer in one of the defined areas, it was often feasible to film a different group of deer on the same day. In order to film a second group of deer, they needed to be located in a non-adjacent area to ensure being a different group of animals. Administration of the sound treatment and digital recordings were obtained during the day (n = 20) and night (n = 20), from 3-18 November 2015. Moon phases during these dates were similar to Phase I, resulting in minimal light available at night.

Behavior Analysis

A total of six 10-sec periods were defined by unique time stamps for each recording. The pretreatment period (Pre Treat) began 1 minute prior to activation of the alert sound. The next four time periods [Sound (T1 –T3)] represent the four consecutive 10-sec time frames following initiation of the sound treatment. The sound treatment itself typically lasted 15 seconds. The final 10-sec period was approximately 1 minute after the T3 period and was considered a post-treatment recovery period (Post-Trt).

All digital recordings were analyzed using video playback software (VLC Media Player for Windows, VideoLAN, Paris, France). Two individuals were trained to identify the described behaviors using digital video recordings from previous research projects. The reviewers completed all analysis independently. Reviewers categorized behavior as number of seconds during each 10-sec observation period that deer exhibited: Passive Behavior (no altered behavior); Alert Behavior (actively observing and/or listening toward the bioacoustics sound/device); Active Behavior (slow to moderate intentional movement toward, or away from the bioacoustics device); or Flight Behavior (running away from the bioacoustics sound/device). Each deer within the field of view of each recording received an individual behavioral analysis. Deer entering or leaving the field of view during the prescribed 10-sec period were included by observation for the appropriate number of seconds, prior to entering or after leaving the field of view, to reach the total of 10 seconds of evaluation.

Statistical Analysis

Analysis of differences in behavioral characteristics between day and night was conducted using one-way ANOVA analysis procedures of IBM SPSS 23.0 (SPSS 23.0, 2013). Duncan Multiple Range Analysis was included to determine if differences in behavioral characteristics changed across days and nights of treatments at the $P \leq 0.05$ significance level.

RESULTS and DISCUSSION

There were no differences in behavioral analysis parameters for number of deer (P = 0.21), Passive Behavior (P = 0.15), Alert Behavior (P = 0.88), or Flight Behavior (P = 0.32) observed between the two reviewers. There was a difference in Active Behavior (P = 0.03), with one observer recording an overall Active Behavior of 0.67 ± 0.05 sec, compared to 0.47 ± 0.04 sec of the 10-sec total observation periods by the second observer. While statistically different, the biological difference may not be relevant, considering the level of variation relative to the large number of data observations collected during the six time periods for each animal during a given treatment event in this study (Phase I, n = 798; Phase II, n = 2,602). Thus, we conclude that overall, behavior analysis between observers was similar. Data recorded for Flight Behavior was so limited due to the evaluation methodology that it was excluded from final analysis.

In Phase I, sound treatments were administered from a single location, in a 1.3-ha grass area surrounded by wooded areas and roads with limited visibility to free-ranging white-tailed deer, on the Berry College campus during day (n = 10) and night (n = 5) hours. This phase of the study was conducted from 6-20 October 2015. During this time period, moon phases were ranged from a waning crescent to waxing crescent, thus incorporating periods of the least additional light available at night.

As expected, prior to administration of the sound treatment (Pre Treat), no difference (P = 0.27) occurred between the day and night recordings (Table 1). Upon administration of the sound treatment, while Passive Behavior decreased in both the day and night, deer exposed to the auditory threat at night exhibited less Passive Behavior (P < 0.02). Alert Behavior following the sound treatment increased at a similar level between day and night. However, deer at night tended to remain alert longer (P = 0.02), more than 1.5 minutes after hearing the bioacoustics sound. Active Behavior following administration of the sound treatment was typically three times longer (P < 0.01) at night (three versus one second) than during the day. During day filming, it was common to observe deer actively seeking the source of the sound, walking in an alert manner toward the direction of the sound-emitting device.

In Phase II, sound treatments were administered from varying locations in lawns and hay fields. These locations were characterized as being more open with limited changes in altitude and/or vegetation that would impair visual appraisal. Similar to Phase I, collection of night data occurred when reflected light from the moon was minimal (3-19 November 2015). Since the fields (56 ha) were divided into different areas, it was possible to film multiple groups of deer in non-adjacent locations within a given day or night. Thus, it was possible to treat and record multiple events during a given day (n = 20), or night (n = 20) within the described dates. It is also important to note that during Phase II, the sound-emitting device was moved to accommodate the location of deer. In each case, the device was placed in a non-visible location, no closer than 100 m to a group of deer. Treatment and filming of behavior occurred at approximately 180° from the device. Thus, activity of the deer relative to the location of the sound emitting device could be determined.

During Phase II, deer behavior patterns observed during the day and night treatments were basically similar with some notable differences from those observed in Phase I (Table 2). During the first 40 sec following administration of the alert call, Passive Behavior occurred for a shorter period of time in the day compared to the night (P < 0.02). Similarly, Alert Behavior occurred

Table 1. Phase I: Average time (sec) white-tailed deer exhibited Passive Behavior, Alert Behavior, or Active Behavior during six defined 10-sec observation periods including administration of the auditory distress blow.

Period	Behavior	Day (n = 108)[b]	Night (n = 23)[b]	P
Pre Treat (-1 min)	Passive Behavior (sec)	9.58 ± 0.18	9.04 ± 0.60	0.27
	Alert Behavior (sec)	0.42 ± 0.18	.78 ± 0.50	0.43
	Active Behavior (sec)	0.0 ± 0.0	.17 ± 0.17	0.03
	Toward (sec)	0.0 ± 0.0	.17 ± 0.17	0.03
	Away (sec)	0.0 ± 0.0	0.0 ± 0.0	
Sound (0-10 sec)[a]	Passive Behavior (sec)	2.4 ± 0.31	1.54 ± 0.67	0.22
	Alert Behavior (sec)	6.75 ± 0.30	7.5 ± 0.68	0.29
	Active Behavior (sec)	.41 ± 0.13	.96 ± 0.37	0.08
	Toward (sec)	.29 ± 0.12	.54 ± 0.32	0.38
	Away (sec)	.12 ± 0.06	.42 ± 0.22	0.07
T-1 (11-20 sec)	Passive Behavior (sec)	1.77 ± 0.34	0.21 ± 0.21	0.02
	Alert Behavior (sec)	7.2 ± 0.36	6.57 ± 0.76	0.44
	Active Behavior (sec)	1.06 ± 0.22	3.36 ± 0.76	0.001
	Toward (sec)	0.68 ± 0.19	1.21 ± 0.54	0.25
	Away (sec)	0.3 ± 0.13	2.14 ± 0.69	0.001
T-2 (21-30 sec)	Passive Behavior (sec)	2.2 ± 0.37	0.07 ± 0.07	0.004
	Alert Behavior (sec)	6.63 ± 0.38	6.82 ± 0.85	0.82
	Active Behavior (sec)	1.0 ± 0.21	3.11 ± 0.86	0.001
	Toward (sec)	0.43 ± 0.16	1.68 ± 0.68	0.006
	Away (sec)	0.60 ± 0.16	1.43 ± 0.67	0.08
T-3 (31-40 sec)	Passive Behavior (sec)	3.27 ± 0.38	0.86 ± 0.51	0.003
	Alert Behavior (sec)	5.48 ± 0.38	6.54 ± 0.84	0.23
	Active Behavior (sec)	1.04 ± 0.23	2.61 ± 0.79	0.01
	Toward (sec)	0.37 ± 0.15	1.61 ± 0.65	0.006
	Away (sec)	0.67 ± 0.17	1.0 ± 0.56	0.46
Post-Trt (100 sec)	Passive Behavior (sec)	6.47 ± 0.45	4.12 ± 0.89	0.02
	Alert Behavior (sec)	3.24 ± 0.43	5.77 ± 0.91	0.008
	Active Behavior (sec)	0.29 ± 0.14	0.12 ± 0.12	0.52
	Toward (sec)	0.09 ± 0.06	0.0 ± 0.0	0.47
	Away (sec)	0.2 ± 0.12	0.12 ± 0.12	0.71

[a] Administration of the bioacoustic alert call occurred for approximately 15 seconds.
[b] Total number of deer observed.

longer in the day (P < 0.07) than night during the same 40-sec post-treatment periods. However, deer during the day exhibited more active behavior (P < 0.001), primarily moving toward the source of the sound treatment. At night, deer tended to move less and not in a consistent direction.

Of particular interest was the observation that deer in the day during both Phase I and Phase II often exhibited investigative behavior. While remaining alert, these deer were frequently observed moving cautiously in the direction toward the sound. At night, when active behavior was evident, deer movement appeared to be more random. The degree of Active Behavior was higher in the more visually confined area of Phase I, compared to the open areas in Phase II. This suggests that use of audio repellents may be more effective in areas where visual appraisal is more limited.

Habituation has been reported to be the biggest challenge related to the limited effectiveness of an auditory repellent (Craven and Hygnstrom 1994, Nolte 1999). It was suggested that bioacoustic sounds may be less prone to habituation, since there is an evolutionary basis for such vocalization within a species (Seamans et al. 2013). At no point in our study did deer fail to respond to the deer alert sound. There was also no indication of habituation (P > 0.05) for any behavioral parameter across all days and nights, in Phase I or Phase II.

Results of this study suggest that visual appraisal does influence the response to an auditory alert call. It should also be noted that use of the white-tailed deer alert call (blow), as administered under the methodology used for this study, would not likely be considered an effective repellent. While an increase in Alert Behavior and Active Behavior was clearly evident, deer rarely left the area

Table 2. Phase II: Average time (sec) white-tailed deer exhibited Passive Behavior, Alert Behavior, or Active Behavior during six defined 10-sec observation periods including administration of the auditory distress blow.

Period	Behavior	Day (n= 250)[b]	Night (n= 196)[b]	P
Pre Treat (-1 min)	Passive Behavior (sec)	9.80 ± .08	9.8 ± .09	0.99
	Alert Behavior (sec)	.2 ± .08	.2 ± .09	0.99
	Active Behavior (Sec)	0.0 ± 0.0	0.0 ± 0.0	
	Toward (Sec)	0.0 ± 0.0	0.0 ± 0.0	
	Away (Sec)	0.0 ± 0.0	0.0 ± 0.0	
Sound (0-10 sec)[a]	Passive Behavior (sec)	2.61 ± .24	3.48 ± .29	0.02
	Alert Behavior (sec)	6.82 ± .24	6.14 ± .30	0.07
	Active Behavior (Sec)	.51 ± .10	.39 ± .12	0.4
	Toward (Sec)	.37 ± .08	.13 ± .07	0.02
	Away (Sec)	.14 ± .06	.26 ± .10	0.27
T-1 (11-20 sec)	Passive Behavior (sec)	2.16 ± .25	4.00 ± .32	0.001
	Alert Behavior (sec)	6.86 ± .26	5.66 ± .32	0.003
	Active Behavior (Sec)	.95 ± .15	.33 ± .11	0.001
	Toward (Sec)	.7 ± .13	.10 ± .07	0.001
	Away (Sec)	.16 ± .07	.25 ± .09	0.44
T-2 (21-30 sec)	Passive Behavior (sec)	2.77 ± .27	4.35 ± .33	0.001
	Alert Behavior (sec)	6.09 ± .29	5.28 ± .33	0.06
	Active Behavior (Sec)	1.07 ± .18	.36 ± .10	0.001
	Toward (Sec)	.96 ± .17	.14 ± .08	0.001
	Away (Sec)	.11 ± .06	.22 ± .07	0.18
T-3 (31-40 sec)	Passive Behavior (sec)	3.49 ± .29	5.28 ± .34	0.001
	Alert Behavior (sec)	5.45 ± .29	4.47 ± .33	0.03
	Active Behavior (Sec)	1.02 ± .17	.19 ± .06	0.001
	Toward (Sec)	.76 ± .16	.06 ± .04	0.001
	Away (Sec)	.24 ± .08	.13 ± .05	0.26
Post-Trt (100 sec)	Passive Behavior (sec)	7.50 ± .26	7.45 ± .31	0.9
	Alert Behavior (sec)	2.08 ± .24	2.15 ± .29	0.85
	Active Behavior (Sec)	.41 ± .11	.4 ± .14	0.94
	Toward (Sec)	.26 ± .08	.17 ± .09	0.46
	Away (Sec)	.12 ± .07	.23 ± .11	0.41

[a] Administration of the bioacoustic alert call occurred for approximately 15 seconds.
[b] Total number of deer observed.

under the definition of Flight Behavior. This study supports the concept for developing devices that incorporate both sight and sound to enhance effectiveness as a repellent as well as reduce the potential of habituation.

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