Human–Wildlife Interactions 8(2):210–217, Fall 2014

Effectiveness of a simulated pack to manipulate wolf movements

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Abstract: Bioboundaries, also called biofences, are deterrents that attempt to exploit certain innate behaviors to exclude wildlife from target areas. We hypothesized that human-deployed scent marks and playbacks of foreign howls could simulate a territorial gray wolf (*Canis lupus*) pack impinging on a resident pack, thereby causing the resident pack to move. During summer 2010, we deployed a simulated-pack bioboundary near 3 wolf packs in northern Wisconsin and monitored their movements relative to 3 wolf packs experiencing a sham treatment, to control for effects of human presence. We analyzed wolves' locations (≥1 location per week) and used linear models with mixed effects to examine distance from the rendezvous site as a function of treatment (sham or experimental) and phase of treatment (before or after treatment was initiated), while accounting for variations in individual wolves. We found little evidence that biofences, as configured and deployed in this study, caused wolves to change use of their territory.

Key words*:* bioboundary, biofence, *Canis lupus*, deterrent, human–wildlife conflicts, nonlethal, rendezvous site, territoriality

Gray wolves (*Canis lupus*) began to recolonize Wisconsin in 1975, and the Wisconsin Department of Natural Resources (DNR) began monitoring the population in 1979 (Wydeven et al. 2009). Recolonization has resulted in increasing wolf–human conflicts, primarily depredations on domestic animals and livestock (Ruid et al. 2009).

Cattle (*Bos* spp.) are the most commonly depredated livestock in Wisconsin (Ruid et al. 2009), and in addition to being economically costly, such conflicts likely result in human intolerance of wolves (Naughton-Treves et al. 2003). Removal of wolves from the federal list of threatened and endangered species and associated regulations restricting take, expanded the range of tools available to managers to address conflict, including targeted lethal removal of depredators and population reduction (Wisconsin DNR 1999). However, lethal removal alone may not be effective in reducing all depredations. Removal through regulated harvest could potentially open up territories for new packs or remove packs which have not had a history of depredation (Way and Bruskotter 2012). Further, consumptive use, such as hunting and trapping, can be controversial and may alienate other stakeholders, despite improving the tolerance of wolves by other groups (Treves and Naughton-Treves 2005).

Use of nonlethal methods may be important to both mitigate social concerns associated with wolf management and reduce livestock depredation (Ruid et al. 2009, Way and Bruskotter 2012). Successful nonlethal methods include translocation of problem animals, livestock guard animals, fladry, and electronic guards (Ruid et al. 2009). Other nonlethal deterrents are disruptive stimuli, such as movement-activated guard devices that emit lights and sound via a passive infrared detector when activated by an animal, and shock collars (Musiani et al. 2003, Rossler et al. 2012). These tools, tested on wolves both in the field and in captivity, are effective for temporary protection of livestock. Adapted animal husbandry, such as pasture selection and calving dates, can

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prevent livestock depredations in some limited situations (Ruid et al. 2009).

Bioboundaries, another class of wildlife deterrents, have not been examined extensively for wolves. The technique attempts to exploit certain innate or learned behaviors to exclude wildlife from targeted areas. Territoriality is an adaptive behavior that allows animals to minimize energy use in a contest over resources and might be harnessed to create a bioboundary for wolves (Mech and Boitani 2003).

We hypothesized that strategically-placed scent marks and recorded howl playbacks could be used in conjunction to simulate a territorial pack impinging on a resident pack, thereby causing the resident pack to move or shift its activity. Our objective was to determine if a bioboundary deterrent changes wolves' use of a territory relative to a sham treatment designed to control for human presence within a wolf territory. We predicted that the distances wolves move would be greater as a result of the deterrent, and that movements would be directed away from the deterrent. If the deterrent had no effect, we predict that wolves' movement distances would not change with treatment and that movement would be random, rather than directional.

Study area

The minimum population count for wolves in Wisconsin during the winter of 2009–2010 was between 690 and 733 wolves in 181 packs (Wydeven and Weidenhoeft 2010). These wolves occupied 33 counties in the northern and central forested region of Wisconsin (Wydeven and Weidenhoeft 2010).

Figure 1. Gray wolf (*Canis lupus; photo courtesy U.S. Fish and Wildlife Service*).

We focused on rendezvous sites, which represent areas of concentrated use. These homesites are used during the post-denning period (late spring to early fall), and pack members rear and defend pups at these locations (Mech and Boitani 2003). Howl surveys are a useful method of identifying rendezvous sites because responses from both pups and adults at the same location during the post-denning period indicate a likely rendezvous site (Harrington and Mech 1982). We conducted howl surveys (23 howl nights, 104 stops) between June 30 and August 6, 2010, along roads in >17 known wolf territories, following protocol developed by Harrington and Mech (1982). We were successful in identifying rendezvous sites of 6 wolf packs, 5 of which were located in the northern forested region of Wisconsin in Oneida, Vilas, and Price counties; the other pack was located in Jackson County, within the central forested region.

We mapped rendezvous sites using acoustic bi-angulation. We estimated the direction of response, from both pups and adults, from 1 observer location using a compass bearing and estimated direction of a second response from a second observer location using a compass bearing within 3 hours of the first response. However, at 3 of the 6 sites, wolves did not make a second response. To map these sites, we estimated the direction of the first response using a compass bearing and estimated the distance wolves were located from the observer based on the volume of the first response. Ground searching to map these sites was not conducted, as it would have disturbed these areas prior to initiating treatment. Each pack had ≥1 animal previously fitted with a VHF telemetry collar by the Wisconsin DNR, and 1 pack had 2 animals collared. Collared animals included known breeding and nonbreeding animals.

Methods

Treatment

To allow for the experiment to be completed during the post-denning period in which wolf movements are concentrated around homesites, treatment at all sites began within a period of 22 days (between July 18 and August 8, 2010) and lasted for 15 days. Stimuli on experimental treatment sites consisted of howl playbacks, and scat and urine scent marks. Howling and scent marking complement one another in the process of territory maintenance, potentially making both vital components of a bioboundary. Howling provides long-range, immediate information to neighboring packs, while scent marking provides more site-specific, long-term information (Harrington and Mech 1979).

We used howl boxes (Figure 2) to produce howl playbacks automatically 3 to 4 times each night. Howl boxes (R. Schultz, Wisconsin DNR) consisted of a cassette voice recorder (RCA® RP3503, Indianapolis, Ind.), timer (Diehl®, Series 884, Napperville, Ill.), amplifier (Pyle®, Brooklyn, N.Y.), directional microphone (Bolide Technology Group Inc., San Dimas, Calif.), outdoor speaker (Pyle®), and marine battery. Depending on site accessibility, we placed howl boxes 800 m to 1,200 m from the estimated rendezvous site. We created the howl playbacks from a parabolic microphone recording of a chorus howl of ≥3 adults and pups in the North Averill Creek Pack (Lincoln County, Wisconsin) recorded in 1980. Use of this recording ensured that the howls would be foreign to all packs used in the study. We manipulated the recording using Audicity 1.3 Beta software to create 4 unique playbacks. Each playback began with an adult howl to simulate a realistic howl sequence. A directional microphone and cassette recorder recorded any responses by wolves for 5 minutes following the first 2 stimuli each night.

We collected fresh scat and urine from a Wisconsin wolf pack (Hoffman Lake Pack) located >80 km from any study site to insure that scents were foreign to all packs being studied. We collected urine during the winter of 2009 to 2010 and collected scat during May and June of 2010. Social status of animals from which the scat and urine were collected was unknown. On day 1 of treatment, we placed scat and urine scent marks at 200-m intervals along an 800-m transect on a road or trail near the howl box because wolves often use roads or trails for travel. We placed urine scent marks on vegetation or other natural features elevated above the ground to simulate a raised-leg urination (RLU) of a dominant animal. We placed scat (approximately 5 x 2 x 2 cm in size) near the simulated RLU and scratched the ground with sticks to simulate territorial marking (Vila et al. 1993). We refreshed all scent marks twice during treatment, on days 5 and 10. Scent marks were not removed at the end of treatment, but rather allowed to degrade naturally.

Figure 2. A howl box unit consisting of an outdoor speaker and parabolic microphone for recording.

At sham-treatment sites, we sought to control for the possibility that human presence could affect movement at a rendezvous site. We deployed howl boxes in the same manner at sham-treatment sites as experimental treatment sites, but we did not initiate howl playbacks. We simulated scent marking by walking 800-m transects on a road or trail nearby the howl box. This treatment ensured equal exposure to human presence at both the experimental and sham-treatment sites.

Monitoring

To monitor wolves' use of their territories, we used telemetry in conjunction with howl

Table 1. Mean distance and standard deviation of pre- and post-treatment gray wolf radio-telemetry locations from howl box and rendezvous site in Wisconsin, 2010.

Wolf	treatment	Howl box				Rendezvous site			
		Pre-treatment		Post-treatment		Pre-treatment		Post-treatment	
		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
W1[a]	Sham	5997	2601	8726	2211	6476	2695	9319	2192
W2[a]	Sham	1297	587	3648	1546	1462	787	3541	1528
W3	Sham	2639	925	3711	2347	2582	882	3622	2394
W4	Sham	1699	1455	1480	394	2225	1247	1960	553
W5	Experimental	995	502	4203	1846	837	435	3861	1772
W6	Experimental	3005	2318	6409	2455	3223	2397	6617	2514
W7	Experimental	1381	1490	3823	2217	1382	1473	3795	2292

[a] Individual wolves are members of the same pack.

surveys, a time tested survey technique. All monitoring was also conducted during the post-denning period, between June 7 and October 7, 2010. Radio locations were provided by the Wisconsin DNR, which conducted aerial telemetry during the study period (≥1 location per week). In addition, we used both traditional howl surveys, as well as automated howl surveys. These automated surveys were conducted using the howl boxes at experimental and sham-treatment sites. The howl boxes, therefore, served 2 functions in this study. Automated surveys were advantageous in that they allowed for monitoring of the sites more frequently than logistical constraints would have otherwise allowed. Automated howl surveys were conducted once every 5 days and consisted of a single adult animal howling 3 times from a prerecorded audiotape (Harrington and Hanson 1986). Following the survey, howl boxes recorded for 5 minutes to capture any vocal responses.

Statistical analysis

We developed 4 generalized linear models to evaluate wolf movement distances. Movement distances were measured between any wolf location (from aerial telemetry and howl surveys) and 2 reference points: the howl box location and the estimated rendezvous site location (2 response variables for distance). Distances were calculated using ArcMap's (Version 9.2) Euclidean distance tool (Table 1). Distances were transformed using a box-cox transformation to meet normality assumptions (Sokal and Rohlf 1995). We estimated an optimal box-cox parameter using likelihood techniques in PROC TRANSREG (SAS 9.2, SAS Institute, Cary, N. C.).

All models included the random variable, wolf, to account for lack of independence in the source of the distance measurements (within a pack, telemetry locations came from a single individual) and random variable, location, to account for method by which the animal was located (radio-telemetry or howl survey). All models also included date (Julian date) to account for serial dependence and the natural tendency for attendance at homesites to decrease over the summer. Other models included treatment, either experimental or sham-treatment, and phase, which refers to the timing of the location, either before or after treatment was initiated. Models were evaluated using corrected Akaike's Information Criterion (AIC_C) and Akaike weights (ωi) (Burnham and Anderson 2002).

We used a parametric concentration parameter to test for wolves' directional movement (Batschelet 1981). Direction of wolf movement was represented by the direction between any wolf location and 2 reference points: the howl box location and the rendezvous site location. Directions were calculated using the same extraction procedure in ArcMap (Version 9.2).

Results

Wisconsin DNR pilots obtained 22, 21, and

Table 2. AIC_C model selection for explanatory models of gray wolf movement in Wisconsin 2010. Wolf (individual) and Location (telemetry or howl survey) are random variables in each model.

Response variable	Model	AIC_C	Δ_i	ω_i
Distance to rendezvous site	Date[a], Phase[b], Treatment[c]	1382.6	0.0	0.98
	Date, Phase	1390.9	8.3	0.02
	Date, Treatment	1406.9	20.3	<0.001
	Date	1415.2	32.6	<0.001
Distance to howl box	Date, Phase, Treatment	1384.2	0.0	0.98
	Date, Phase	1392.2	8.0	0.02
	Date, Treatment	1406.6	22.4	<0.001
	Date	1414.8	30.6	<0.001

[a] Date refers to the Julian date when location was obtained.
[b] Phase refers to the timing of the location, either before or after treatment was initiated.
[c] Treatment refers to pack assignment to experimental or sham treatment.

21 locations on radio-collared wolves in the 3 experimental treatment packs and 10, 22, 15, and 16 locations for radio-collared wolves in the 3 sham-treatment packs (1 pack had 2 animals collared). Wolves responded vocally 6 times to experimental treatment playbacks (67 playbacks, or a response rate of 9%). Response rate to playbacks was not significantly different from responses to all traditional howl surveys conducted during the study for rendezvous site location and post-treatment monitoring ($t_{193} = -0.19$, $P = 0.85$). All responses to playbacks occurred within the first 8 days of a 15-day treatment period. While in the field, we noted increased scent marking and tracks at experimental treatment sites (overmarks), especially in the vicinity of scent transects. We did not quantify overmarks. At 1 site, a radio-collared wolf was located via aerial telemetry <100 m from the howl box location during day 2 of treatment.

AIC_C model selection suggested that response variables (i.e., distance from the howl box and distance from the rendezvous site) were best explained by the date, phase, and treatment model, rather than either the models with phase or treatment alone or the null model (Table 2). Model selection suggested strong support for this model ($\omega i = 0.98$; Table 2). In the optimal model, phase was significant (rendezvous site, $P = 0.004$ and howl box, $P = 0.01$), but treatment was not significant (rendezvous site, $P = 0.62$ and howl box, $P = 0.77$). Movement distance was larger during post-treatment for both response variables. In addition, we calculated a parametric concentration parameter for each individual wolf and found that none of the wolves monitored in the study displayed directional movement (Table 3).

Discussion

AIC model selection suggested that both distance response variables were best explained by the model that included treatment and phase. However, examination of fixed effects suggested that phase was important, but treatment was not. The concentration parameter test revealed that wolves showed no directional movement regardless of whether their pack was an experimental or a sham-treatment pack. Taken together, there is little evidence that the deterrent, as configured and deployed in this study, caused wolves to change use of their territory.

Previous tests of bioboundaries or biofences indicate mixed effectiveness. Ausband et al. (2013) explored the use of human-deployed scent marks to manipulate wolf movements in 3 wolf packs in Idaho, USA. Biofences, consisting of wolf scat and urine scent marks, were deployed in areas of wolf territory within >50% kernel density home range estimates. Location data from satellite-collared wolves and sign surveys, during the first year of trial, indicated that wolves either did not trespass biofences or trespassed little, while in the second year, wolf movements were not affected. In a similar effort, Jackson et al. (2012) investigated the

Table 3. Concentration parameter (R) for pre- and post-treatment gray wolf radiotelemetry locations from 2 reference points (howl box and rendezvous site) in Wisconsin, 2010.

		Howl box		Rendezvous site	
Wolf	Treatment	$R_{\text{pre-treatment}}$	$R_{\text{post-treatment}}$	$R_{\text{pre-treatment}}$	$R_{\text{post-treatment}}$
W1[a]	Sham	1.54	1.78	3.15	2.63
W2[a]	Sham	1.56	1.38	1.38	0.58
W3	Sham	4.26	4.26	2.21	1.98
W4	Sham	3.19	1.96	2.61	2.10
W5	Treatment	0.66	5.11	1.43	1.52
W6	Treatment	1.97	1.21	1.16	2.74
W7	Treatment	1.93	4.71	2.11	2.02

[a] Individual wolves are members of the same pack.

effectiveness of scent-mark deployment to contain a pack of translocated wild dogs on the Northern Tuli Game Reserve in Botswana, Africa. Trials consistently resulted in the pack moving toward the center of their territory, within the confines of the protected area. We expanded upon this work in 2 ways: by integrating an additional territoriality cue (i.e., howl playbacks) and by using sham treatment to control for effects of human presence. Our changes were important because significance of phase in the AIC_C-optimal model might indicate that wolves changed their movement patterns in response to human presence near rendezvous sites. In this case, magnitude of wolf movements increased after experimental and sham treatments were initiated and when human presence began. This is consistent with literature that demonstrates that even small amounts of human disturbance can influence wolves' use of their territory. Specifically, wolves were more likely to abandon homesites and move pups >5 weeks of age in response to disturbance (Frame et al. 2007). In Wisconsin, pups are 5 weeks of age at approximately the third week in May (A. Wydeven, Wisconsin DNR, unpublished data).

Older pups are more mobile and more able to travel and hunt with the pack, and as a result, wolves generally become more nomadic in late fall and through the winter (Mech and Boitani 2003). However, the use of date as a random variable should have accounted for variation over time, and significance of phase in the best model suggests that human activity had an effect. These results confirm the importance of including sham-treatments in experiments exploring the effectiveness of biofencing or bioboundaries.

Despite little evidence that treatment affected wolf movements, wolves responded stereotypically to our simulated packs. At some experimental treatment sites, wolves responded to the playbacks vocally and with increased scent marking. This is consistent with findings in which resident wolves overmarked 6% of human-deployed scent marks on the primary line of biofencing (Ausband et al. 2013).

Our results may also indicate something about the critical importance of rendezvous sites and may provide further support for the protections given to these sites in wolf management plans. Others have hypothesized that when pups are young and immobile or if wolves have another critical resource to defend, such as a kill, the benefits of remaining at a homesite may be high (Harrington and Mech 1979). If rendezvous sites are a critical resource, wolves may choose to remain on the site rather than retreat in response to unidentified howls and scent marks.

The location of a bioboundary relative to the area of concentrated use may be critical in determining its effectiveness. Such a deterrent may yet prove to be effective in other, more peripheral portions of wolf territory that are not strongly defended and used frequently. Ausband et al. (2013) demonstrated limited effectiveness in areas of territories within >50% kernel density home range estimates.

Alternatively a bioboundary located nearer to a homesite than those distances used in this study may be necessary to shift movements.

Additionally, structure of the pack might influence effectiveness of this deterrent. Well-established packs typically use the same homesites from year to year and may be less likely to abandon them. Bioboundary deterrents might be more effective in cases either where the pack structure is broken up or in recently established rendezvous sites of new wolf packs.

Wolf movement patterns did not appear to be influenced by a simulated-pack deterrent. However, they did respond to the deterrent with territorial marking behaviors similar to those they would use to an encroaching pack of wolves. Wolves hold and defend rendezvous sites tenacioiusly. Altering wolf use of rendezvous sites, especially early in summer within well-established packs, will be difficult to do. These results provide evidence that, in general, bioboundaries warrant investigation. Bioboundary deterrents should be considered as we look to create variety of effective tools to work toward reduced human–wildlife conflict.

Acknowledgments

Thanks to R. P. Thiel, R. L. Jurewicz, and J. E. Wiedenhoeft for their input on study design. C. Williamson and R. Leonard provided valuable assistance in the field. We thank the University of Wisconsin–Madison Department of Forest and Wildlife Ecology. Support for this work was provided by the Berryman Institute, the Woodrow Wilson Foundation, and the Wisconsin Department of Natural Resources.

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