Steady Sound, Not Fuel: White-tailed Deer Return Times After Stewardship Machines on a Restored Prairie–Savanna (submitted to *Ecological Restoration*, 11.05.2026)

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Abstract

Routine land management can alter wildlife behavior without reducing abundance, and the sound of human activity is hard to separate from human presence itself. On one restored prairie–savanna in northern Wisconsin the same trails are worked on foot, on a near-silent battery-electric utility vehicle (UTV), and behind two gas engines of opposite acoustic character, a steady mower and a sputtering all-terrain vehicle (ATV), almost entirely in daylight. From a steward-conducted full-frame camera census (11,820 labeled frames, January 2024–June 2026), I measured how long white-tailed deer (*Odocoileus virginianus*) took to return to a camera after a human pass by each conveyance, as a ratio to the deer's own baseline inter-visit interval (8.61 h). Deer returned on or ahead of schedule after the electric cart (ratio 0.83, n = 146 return intervals) and the steady mower (0.73, n = 67), at baseline after foot passes (1.02, n = 369), and later after the ATV (1.64, n = 69). Return times after the continuous-sound machines were shorter than after the ATV (Mann–Whitney U = 5542.5, $p = 0.002$ for all deer; U = 4896.0, $p = 0.0005$ for does), whereas an electric-versus-gas split was not significant. Even the ATV's effect was a delay of hours, not avoidance. The implication for practice is low-cost: steady, continuous stewardship machinery disturbs the land's most abundant animal measurably less than intermittent, sputtering equipment, largely independent of fuel. The limits are a single site, a short series with one thin year, and relative rather than absolute metrics.

Keywords: anthropogenic noise, camera trapping, human disturbance, *Odocoileus virginianus*, recreation ecology

Restoration Recap

- Restoration work means machines on the ground, and managers often assume electric equipment is gentler on wildlife than gas.
- On a restored prairie–savanna in Wisconsin, trail cameras recorded for three years how quickly white-tailed deer returned after passes on foot, on a silent electric cart, behind a steady gas mower, and behind a sputtering gas ATV.
- Deer returned on or ahead of schedule after the electric cart and the steady mower alike; only the intermittent ATV delayed them, and only by hours.
- What deer weigh is the continuity of a machine's sound, not its fuel.
- For practice: favor steady-running equipment, keep engines tuned and the throttle even, and plan work to avoid start-and-stop patterns. Electrification is not required to lessen disturbance.

Introduction

Human activity reshapes wildlife behavior across a gradient that runs from outright displacement to subtle shifts in timing, even in the absence of any change in population size. A now-substantial literature documents human-induced nocturnality, in which mammals shift activity into darker hours to avoid people (Gaynor et al. 2018), and camera-trap studies routinely quantify how species distribute activity around human presence using relative activity indices and activity-overlap coefficients (Ridout and Linkie 2009, Rowcliffe et al. 2014, Frey et al. 2017). Recreation ecology has shown that even non-consumptive human use can carry

behavioral costs for wildlife (Larson et al. 2016), and that the form of the disturbance (pedestrian, cyclist, motorized) can matter as much as its intensity.

One component of human disturbance that is conceptually distinct but empirically entangled is noise. Anthropogenic noise alone can alter foraging, vigilance, and habitat use in birds and mammals (Shannon et al. 2016), yet in most field settings noise arrives bundled with the visual and olfactory presence of people and vehicles, so its independent contribution is hard to estimate. And noise is not one thing. A steady, predictable drone and an intermittent, sputtering report differ in how alarming they are: predictable, continuous stimuli permit habituation, whereas irregular, start-and-stop ones resist it and keep signaling novelty. Separating presence from sound, and steady sound from intermittent sound, normally requires either an experimental playback design or an unusually controlled setting in which the same people, on the same routes, at the same times, differ only in the machine that carries them and the sound it makes.

The property described here is such a setting. It is a restored prairie–savanna and adjacent woodland on the Namekagon River in northern Wisconsin, worked by a single household that maintains a decade-long trail-camera record and labels every frame the cameras produce, wildlife and people alike, as a full-frame census rather than a sample. The same trails are traveled on foot, on a battery-electric utility vehicle that is effectively silent, and behind two gas engines that differ in sound: a mower that runs at a steady, even tone, and an all-terrain vehicle whose note is intermittent and sputtering. Because all are operated by the same people over the same routes and, with few exceptions, in daylight, the time-of-day confound that dogs most human-avoidance comparisons is largely removed, and the contrast among the machines approximates a natural experiment, not on fuel type but on the character of the sound a working

machine makes. White-tailed deer (*Odocoileus virginianus*), the most abundant and most human-tolerant animal on the property, are the natural test species: abundant enough to yield adequate return-interval samples, and tolerant enough that any measurable delay is informative rather than swamped by outright avoidance.

Here I ask a single, management-relevant question, and then a sharper one behind it: after a human pass, do deer return to a site more slowly behind some machines than others, holding time-of-day and route roughly constant, and if they do, is the variable they respond to the fuel (electric versus gas) or the sound (steady versus intermittent)? I report the answer across three years, and I am explicit about where the evidence is firm and where it is not.

Methods

Study Site and Monitoring

Ten camera stations span prairie and woodland across the property, positioned at trail junctions and along the working loops. Cameras of two makes and six models (Browning BTC-5, BTC-5HDX, BTC-5P and BTC-7EHP5U, Prometheus Group, Birmingham, AL; GardePro A3 and A3S, GardePro, Shenzhen, China) run continuously. Every image is labeled by the resident steward for species, an age/sex class where determinable, a count and an estimated number of individuals, a day/night flag, and habitat, and each frame is joined to its EXIF timestamp, hour, and camera. The analysis window is 1 January 2024 through 30 June 2026, comprising 4,248 labeled frames in 2024, 5,787 in 2025, and 1,785 in the first half of 2026.

Independent Detections and Conveyance Coding

Consecutive frames of the same category at one camera within 30 minutes were collapsed into a single independent detection to limit autocorrelation; camera model served as the station proxy for this collapsing. Human passes were classified by conveyance from the age/sex/notes field

into four categories: on foot; electric UTV (the silent battery cart); a steady gas engine (the mower, whose sound is an even, continuous tone); and an intermittent gas engine (the ATV, whose sound is a variable, sputtering note). The two gas machines are kept as separate classes rather than pooled into a single gas-engine category because they are acoustically opposite, the mower steady and continuous, the ATV intermittent and sputtering, and, as the results show, deer respond to that difference. Group passes with no identifiable conveyance, and four gas passes labeled only as a vehicle, were excluded from the conveyance analysis. About 94% of machine frames fell between 06:00 and 20:00 (electric 94%, mower 97%, ATV 93%), so the machine comparisons are made almost entirely within daylight hours.

Return-Interval Metric and Tests

For white-tailed deer I computed a baseline inter-visit interval as the median time between consecutive independent deer detections at a camera, capping gaps at seven days. For each human pass of a given conveyance, I found the next independent deer detection at the same camera within seven days and recorded the elapsed time (the return time). The response ratio for each conveyance is the median return time divided by the deer baseline (8.61 h pooled; 10.79 h for does alone), so a ratio near 1 indicates return on the animal's normal schedule and a ratio above 1 indicates delay. I report the four-way description across machines with sample sizes, medians and interquartile ranges (Table 1), and then the primary hypothesis test, a two-sided Mann–Whitney U test contrasting return times after the continuous-sound machines (electric cart and steady mower pooled) against those after the intermittent machine (the ATV). This continuity grouping is the theoretically motivated axis; pooling on it, rather than on fuel, is what recovers statistical power from a per-machine split that necessarily thins each cell. Three further pairwise tests check the grouping itself: electric cart versus steady mower (which should not

differ if sound continuity is what matters), steady mower versus ATV (the two gas machines, which should), and foot versus the continuous machines (Table 2). Tests were run for all deer and for the doe comparator, pooled across the three years and separately by year, with a sensitivity analysis that relaxes the independent-pass collapsing of human triggers reported alongside the primary result. Statistics were computed in Python (v. 3.10, Python Software Foundation, Wilmington, DE); the full pipeline and the labeled frame table are retained.

Two child-safety and stewardship conventions were maintained: any frame flagged as possibly containing a minor was counted only and never described or identified, and black-bear frames were separately flagged.

Results

Resolved by machine, deer return times sorted not by fuel but by the character of the sound (Table 1, Figure 1). Against a deer baseline inter-visit interval of 8.61 h, pooled three-year return ratios were 1.02 for foot passes (median 8.8 h, n = 369 return intervals), 0.83 for the silent electric cart (7.2 h, n = 146), 0.73 for the steady gas mower (6.3 h, n = 67), and 1.64 for the intermittent gas ATV (14.2 h, n = 69). The two continuous-sound machines, one electric and one gas, both drew deer back on or ahead of their ordinary schedule and sat together below baseline; the ATV alone rose well above it. Critically, the steady gas mower patterned with the electric cart, not with the other gas machine: fuel did not predict the response, sound continuity did.

The primary test confirms the picture. Return times after the continuous-sound machines were shorter than after the intermittent ATV, pooled across all three years (Mann–Whitney U = 5542.5, n = 213 and 69, $p = 0.002$ for all deer; U = 4896.0, n = 211 and 65, $p = 0.0005$ for does). Resolved to the doe comparator, whose year-round presence gives the most stable baseline, does returned at a ratio of 0.84 after continuous machines and 1.66 after the intermittent ATV. The

pairwise checks of the grouping behave as the sound hypothesis predicts (Table 2): the electric cart and the steady mower did not differ (U = 4812.0, $p = 0.85$ for all deer; $p = 0.95$ for does), whereas the two gas machines did (mower versus ATV, U = 1723.0, $p = 0.010$ for all deer; U = 1554.0, $p = 0.005$ for does).

By year, the contrast held in the two adequately sampled years, 2025 (U test, n = 147 and 38, $p = 0.014$ for all deer; $p = 0.006$ for does) and the first half of 2026 (n = 46 and 23, $p = 0.075$ for all deer; $p = 0.043$ for does), with the ATV ratio at 1.57 and 2.10 respectively (Figure 2). In 2024 the machines were barely used on camera (8 electric, 12 mower and 8 ATV return intervals) and all three machine ratios fell below baseline, so that year contributes little either way; the pooled result rests on 2025 and 2026.

Two further patterns in the doe record deserve note. First, does returned more slowly after a person on foot (ratio 1.20, median 13.0 h against a doe baseline of 10.79 h) than after the continuous machines (0.84; U = 30863.5, $p = 0.0005$), so a walking person was, to the does, more of a disturbance than a passing cart or mower. Second, bucks, who are present mainly in the hard-antler season and give far fewer return intervals (31 after the ATV), returned slowly after every kind of pass (ratios 1.9–2.9) and showed no continuity contrast ($p = 0.38$); the sound discrimination reported here is a doe, and all-deer, result.

All of these machine effects are mild in absolute terms. The home herd's deer return, overall, close to their ordinary schedule, and even the ATV, the one machine they clearly mind, lengthens their return only to a median of roughly 14 h against an 8.6 h baseline, with a wide spread (interquartile range 4.5–26.9 h). That is a delay of hours, not the outright avoidance a genuinely threatening disturbance would produce: the deer are registering the sputtering engine, not fleeing it.

Why the split matters is worth showing directly. Pooling the two gas machines into a single gas class obscures the pattern: that class averages the quiet mower (0.73) with the sputtering ATV (1.64) into a middling 1.03, so a simple electric-versus-gas contrast comes out only directional for all deer (U = 8789.5, $p = 0.10$ pooled) and marginal for does ($p = 0.039$). Resolving the machines by the character of their sound recovers the effect that pooling dilutes. A sensitivity analysis using raw human frames as triggers, which increases the effective sample (n = 269 and 78), reproduces the continuity result and strengthens it (U = 7600.5, $p = 0.0002$ for all deer), and does not disturb the ordering among machines.

Discussion

The pattern is what a noise-and-predictability hypothesis predicts. Holding the operators, the routes, and the time-of-day approximately constant, deer resumed use of a site quickly after continuous machine sound, whether that sound came from a silent electric motor or a steady gas engine, and slowly only after intermittent, sputtering sound. Because the visual and olfactory human cues are shared across all the machines and the temporal niche is held within daylight, the residual difference points squarely at the acoustic channel, and within it at one specific property of the sound: its continuity. The engine's fuel is not what deer weigh; the regularity of its note is.

Why the steady mower behaves like the silent cart, rather than like the other gas machine, is the interpretive heart of the result. A continuous, even drone is a poor alarm cue: it is predictable, it does not startle, and it admits the ordinary process of habituation by which familiar wildlife come to discount a known disturbance. An intermittent, irregular report, the start-and-stop, rev-and-idle signature of an ATV worked across rough ground, resists habituation precisely because it keeps changing; each new burst reads as a fresh event. This is consistent with the broader evidence that anthropogenic noise carries independent behavioral costs

(Shannon et al. 2016), and it refines the common intuition that electric means quiet means gentle, and gas means loud means harsh. On this ground the operative variable was not electric versus gas at all, but steady versus sputtering. The doe record adds a complementary reading: a person walking, who pauses, looks and lingers, delayed the does more than either continuous machine did, which suggests that what a passing machine lacks is not only alarming sound but the attention of a standing human.

What is and is not novel here should be stated plainly. The analytical tools are entirely standard: relative activity and return-interval indices, independent-detection collapsing, and activity-overlap thinking are established camera-trap methods (Ridout and Linkie 2009, Rowcliffe et al. 2014, Frey et al. 2017), and the framing of human disturbance as a driver of altered activity follows Gaynor et al. (2018) and the recreation-ecology literature (Larson et al. 2016). The disturbance axis this contrast probes has just been read at its far extreme: Kudrenko et al. (2026) documented Chornobyl wildlife shifting their activity under the acute disturbance of war and human displacement. The present study occupies the opposite pole, the quietest, most familiar forms of human presence, resolved to the difference between a steady and a sputtering engine, so that the same instrument, from the shock of war to the sound of a utility vehicle, measures one continuous gradient of how wildlife answer the human. Two features appear uncommon in this exact combination. First, the data are a steward-conducted, multi-year, full-frame census of a single restored prairie–savanna, which yields dense, behaviorally usable return-interval samples for a tolerant focal species. Second, the design is a controlled within-property natural experiment that isolates not the presence of an engine, nor its fuel, but the acoustic character of the sound it makes, a contrast made possible because the same household operates a silent electric UTV, a steady mower, and an intermittent ATV over identical routes at

similar times. The contribution is therefore less methodological than evidentiary: a rarely available design brought to bear on a specific, actionable question, with a result that redirects the management lever from fuel choice to sound quality.

If the direction of the effect is real, and its agreement across the two well-sampled years, together with the pooled significance on the continuity axis and the pairwise agreement of the cart and the mower, is the strongest argument that it is, the management implication is simple and low-cost, and different from the one an electric-versus-gas reading would have suggested. It is not that a property must electrify to spare its wildlife; it is that steady, continuous machine sound is measurably less disturbing than intermittent, sputtering sound. A well-tuned continuous engine can be as gentle as a silent one, and a quieting benefit is available to any manager who favors steady equipment, dampens intermittent noise, or plans work to avoid the start-stop patterns that read to deer as a string of new alarms. The home property's deer are notably tolerant, a tolerance that appears specifically relational, a herd at ease with a familiar family and its routine machines rather than one indifferent to disturbance, and it is precisely that relational tolerance, together with the near-baseline return times it produces, that makes the property a clean instrument on which a within-property sound contrast can be read at all.

Limitations

The caveats are several and they matter. First, the metric is relative abundance and return timing, not occupancy or density; it describes detection and displacement rather than true presence probability, and it cannot fully rule out that some of the difference reflects fine-scale movement rather than avoidance per se (Sollmann et al. 2013, Burton et al. 2015). A formal occupancy or time-to-event (survival) model with covariates would be the appropriate next step. Second, camera model stands in for physical station in the independent-detection logic, which risks

pseudoreplication where several cameras share a model; a station-level analysis with camera serials would tighten this. Third, resolving the machines into four classes thins each cell: the two gas classes are the smallest (67 and 69 return intervals pooled), 2024 contributes almost nothing, and the per-machine point estimates for the smaller classes and single years should be read as directional. The continuity grouping is what restores power, and its pooled significance (p = 0.0005 for does) is the strongest statement the data support. Fourth, this is one site with one primary observer, and observer-consistent labeling, a strength for internal comparability, is also a single point of potential systematic bias. Fifth, the series is short (three years, the last a half-year weighted toward the fawning season), so single strong or weak years can move an estimate. Finally, although machine use is almost entirely diurnal, machine trips are not randomized within the day or across weather, so residual confounding cannot be excluded. None of these is fatal to the observation, but together they define it as a hypothesis-strengthening result from an uncommon design rather than a confirmatory test.

Conclusion

The conclusion is modest and useful. On a single restored prairie–savanna, over three years, white-tailed deer returned to their haunts on or ahead of schedule after continuous machine sound, electric or gas, and more slowly only after an intermittent, sputtering engine, holding presence and time-of-day roughly constant. It is the continuity of the sound, not the fuel, that the land's most abundant animal weighs: a small, repeatable, and actionable signal that quiet, steady stewardship is gentler on the land. The honest limits are foregrounded above: a single site with one observer, a short series with one thin year, modest samples for the two gas machines, and a relative-abundance rather than an occupancy metric. Within those limits, the result is best read as

a directionally consistent, management-relevant lead from an uncommon within-property design rather than a settled effect.

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Table 1. White-tailed deer return times after human passes by conveyance on the home ground, pooled January 2024–June 2026. Return time is the interval from an independent human pass to

the next independent deer detection at the same camera (seven-day cap); the ratio divides the median return time by the deer baseline inter-visit interval (all deer 8.61 h; does 10.79 h).

Deer	Conveyance	Sound	Passes (n)	Return intervals (n)	Median return (h)	Interquartile range (h)	Ratio to baseline
All deer	On foot	—	394	369	8.75	4.43–18.60	1.02
	Electric UTV	Silent	153	146	7.18	3.90–12.83	0.83
	Gas mower	Steady, continuous	67	67	6.27	4.07–13.82	0.73
	Gas ATV	Intermittent	71	69	14.15	4.45–26.90	1.64
Does	On foot	—	394	355	12.96	6.00–29.49	1.20
	Electric UTV	Silent	153	144	9.12	4.50–18.40	0.85
	Gas mower	Steady, continuous	67	67	9.03	4.87–19.53	0.84
	Gas ATV	Intermittent	71	65	17.90	7.33–34.00	1.66

Table 2. Two-sided Mann–Whitney U tests of deer return times between conveyance classes, pooled 2024–2026. Continuous machines are the electric UTV and the gas mower together.

Comparison	All deer: n	U	p	Does: n	U	p
Continuous machines vs. gas ATV (primary test)	213, 69	5542.5	0.002	211, 65	4896.0	0.0005
Electric UTV vs. gas mower	146, 67	4812.0	0.85	144, 67	4797.5	0.95
Gas mower vs. gas ATV	67, 69	1723.0	0.010	67, 65	1554.0	0.005
On foot vs. continuous machines	369, 213	34274.0	0.010	355, 211	30863.5	0.0005
Electric vs. gas (mower and ATV pooled)	146, 136	8789.5	0.10	144, 132	8139.5	0.039
Continuous vs. ATV, raw human frames as triggers	269, 78	7600.5	0.0002	267, 74	6697.0	<0.0001

Figure Captions

Figure 1. White-tailed deer return-to-site ratio (median return time divided by the baseline inter-visit interval of 8.61 h) after human passes, by conveyance, pooled January 2024–June 2026, with the number of return intervals above each bar. The dashed line marks return on the deer's

ordinary schedule; the two continuous-sound machines sit together below it and only the intermittent gas ATV rises above it.

Figure 2. The same ratio by year for the two continuous-sound machines pooled and for the gas ATV, for all deer and for does, with the number of return intervals above each bar. The contrast holds in 2025 and the first half of 2026; machine use on camera was too sparse in 2024 to inform the comparison.