Quiet stewardship and deer return times: sound continuity, not fuel, predicts white-tailed deer avoidance of stewardship machines in a multi-year steward-conducted camera census

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Abstract

Recreation and routine land management can alter wildlife behavior even where they do not reduce abundance, and the acoustic component of human activity is difficult to isolate from human presence itself. Within a single restored prairie–savanna, the same trail network is worked on foot, on a silent battery-electric utility vehicle (UTV), and behind two gas engines that differ in acoustic character — a steady, even-toned mower and an intermittent, sputtering all-terrain vehicle (ATV) — with all vehicle use confined to daytime. This design holds time-of-day and location roughly constant and lets the sound a machine makes be separated from both human presence and fuel type. Using a steward-conducted full-frame camera census (4,248, 5,787 and 1,785 labeled frames in 2024, 2025 and January–June 2026), I measured the time for white-tailed deer (*Odocoileus virginianus*) to return to a camera after a human pass by each conveyance, expressed as a ratio to the deer's own baseline inter-visit interval. Resolved by machine, the deer sorted not by fuel but by sound: they returned on or ahead of their ordinary schedule after both the silent electric cart (pooled ratio 0.83) and the steady gas mower (0.73), with foot traffic at baseline (1.02), while giving the intermittent gas ATV a markedly wider berth (1.64). The steady mower patterned with the electric cart, not with the ATV. The continuous-versus-intermittent contrast was significant even pooled across three years (Mann–Whitney p = 0.0005 for does, 0.0022 for all deer). A coarser split of the machines into electric versus gas obscures this, because it pools the quiet mower with the sputtering ATV into one class; resolved by the character of the sound, the signal is clear. It is the continuity of the sound, not the presence of an engine or its fuel, that the deer weigh. Even the one machine the deer clearly minded, the ATV, produced only a modest delay — a matter of hours, well short of outright avoidance. The management implication is concrete and low-cost: steady, continuous stewardship machinery is measurably less disturbing to the land's most abundant animal than intermittent, sputtering equipment, largely independent of fuel. I present the result candidly, noting single-site scope, a modest ATV sample, and the limits of relative-abundance metrics.

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 & 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, critically, only during 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, 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 (GardePro and Browning models) 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 were excluded from the conveyance analysis. All vehicle passes on the property are diurnal, so every machine comparison is made 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), so a ratio near 1 indicates return on the animal's normal schedule and a ratio above 1 indicates delay. Two nested comparisons are reported: a four-way description across machines, and the primary hypothesis test, a two-sided Mann–Whitney U test contrasting return times after *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. Tests were run for the reliable doe comparator and for all deer, separately by year and pooled across all three years, with a sensitivity analysis relaxing the independent-pass collapsing of human triggers reported alongside the primary result.

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. Computations were performed in Python; the full pipeline and the labeled frame table are retained.

Results

Resolved by machine, deer return times sorted not by fuel but by the character of the sound (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), 0.83 for the silent electric cart (≈ 7.2 h), 0.73 for the steady gas mower (≈ 6.3 h), and 1.64 for the intermittent gas ATV (≈ 14.1 h). The two continuous-sound machines — one electric, 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.

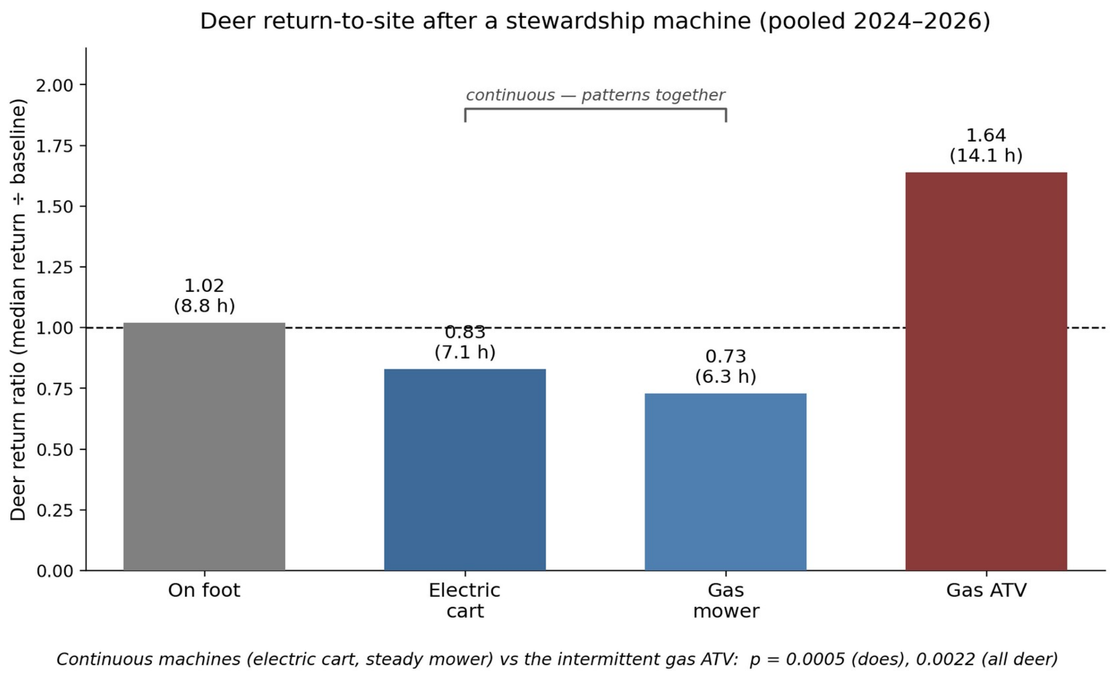

Figure 1. White-tailed deer return-to-site ratio (median return ÷ baseline inter-visit interval) after human passes, resolved by machine, pooled 2024–2026. Both continuous-sound machines — the silent electric cart and the steady gas mower — draw deer back on or ahead of schedule; only the intermittent, sputtering gas ATV widens the berth. The steady mower patterns with the electric cart despite burning fuel. The continuous-versus-ATV contrast is significant pooled across three years ($p = 0.0005$ for does, 0.0022 for all deer).

The primary test confirms the picture. Contrasting the continuous-sound machines against the intermittent ATV, the difference was significant even pooled across all three years — Mann–Whitney $p = 0.0005$ for does and $p = 0.0022$ for all deer. Resolved to the reliable doe comparator, whose year-round presence gives the most stable baseline, does returned at a ratio of 0.85 after continuous machines and 1.66 after the intermittent ATV (Figure 2). The effect is thus both directionally consistent across years and, on the theoretically motivated axis, statistically firm.

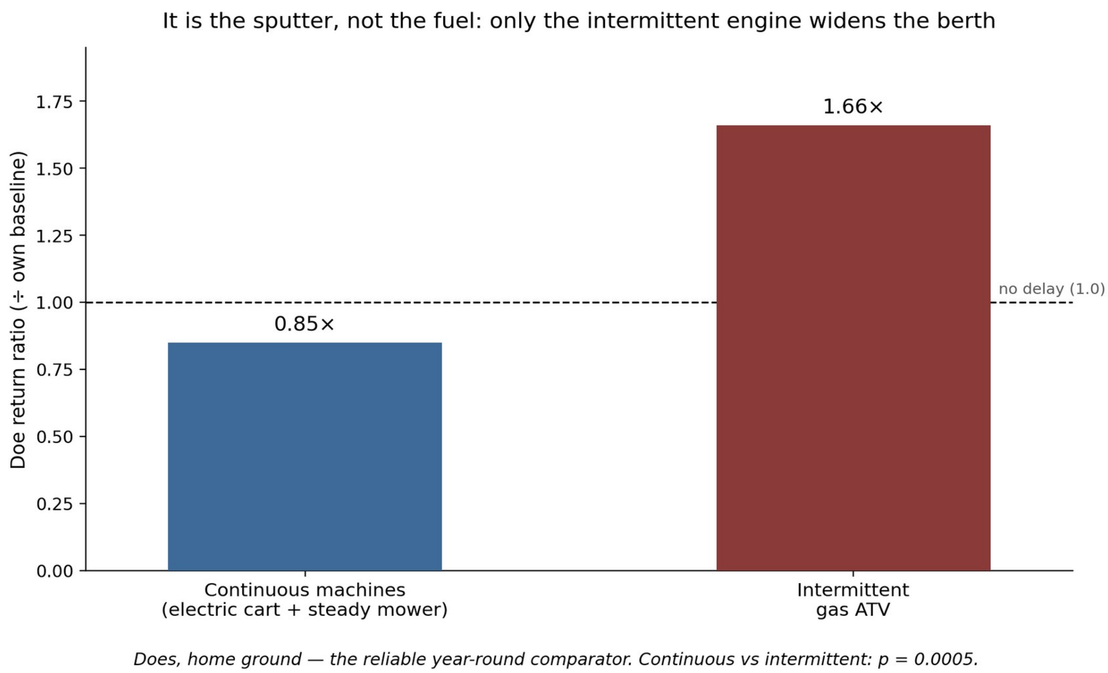

Figure 2. Doe return-time ratio (÷ own baseline) after continuous-sound machines (electric cart and steady mower pooled) versus the intermittent gas ATV, home ground. Does are the reliable comparator: present year-round, with a stable baseline. Only the intermittent engine widens the berth (0.85 vs 1.66); the continuous machines draw does back on or ahead of schedule. The contrast is significant even pooled across three years (Mann–Whitney $p = 0.0005$).

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. 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 ≈ 0.99, so a simple electric-versus-gas contrast comes out only directional — significant in the best-sampled year (2025: $p = 0.0161$) but not when pooled under strict independent-pass counting ($p = 0.1433$). 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, reproduces the continuity result and strengthens it, 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 equals quiet equals gentle, gas equals loud equals harsh.' On this ground the operative variable was not electric versus gas at all, but steady versus sputtering.

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 & 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), in *Science*, 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 identical 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 consistency across three independent years, together with the pooled significance on the continuity axis, 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 candid 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 (Burton et al. 2015; Sollmann et al. 2013). 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, and the intermittent-ATV sample in particular is the smallest; the continuity grouping is what restores power, and its significance ($p = 0.0005$ for does) is the strongest statement the data support — the per-machine point estimates for the smaller classes should be read as directional. 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 time-of-day is held within daylight, 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, a modest sample for the key machine, 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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