Mud Track Plots: An Economical, Noninvasive Mammal Survey Technique

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Abstract - The active component (e.g., bait or scent lures) common to mammal survey techniques can bias detectability (e.g., aversion or attraction) and reduce their efficacy for spatially explicit, habitat-use research. We overcame this obstacle with 1-m^2 mud track plots, which use natural ground substrates to sample mammalian species' occupancy with minimal bias of natural movements. Performance of this method was based on criteria that included implementation effort, cost, species detection, proportion of plots to capture tracks, and species identification by track capture. Mud track plots were quickly established, maintained, and monitored with minimal effort and cost. We recorded tracks in 85% of plots over 8 nights, documented all visually confirmed medium and large-sized mammals (>800 g), and captured identifiable (>98%) tracks on a row-crop farm in the Mississippi Alluvial Valley. Drawbacks included limited application for small mammals, potential ambiguity of using track imprints for species identification, and weather-dependent, spatio-temporal restrictions. Mud track plots are an inexpensive, simple approach to noninvasive mammal detection.

Introduction

Occupancy information provides insight on a variety of spatio-temporal habitat-use patterns and ecological effects (Vojta 2005). Several noninvasive (i.e., does not require capture or handling) survey techniques have been successfully implemented to obtain occupancy data for varied taxa and research objectives (Connors et al. 2005, Mooney 2002, Savidge and Seibert 1988), with some common methods including camera traps, track plates, snowtracking, scent stations, and scat surveys (Gompper et al. 2006). The versatility and low-cost of track-plate methods has resulted in their use to evaluate area species-richness (Silveira et al. 2003), predator activity (Connors et al. 2005, Kuehl and Clark 2002), general habitat-use (Fecske et al. 2002), relative abundance (Mooney 2002), and species occupancy (Mowat et al. 2000, Smith et al. 2007). The efficacy of track plates depends on artificial components (e.g., bait, scent, boxed enclosures, or media-tracking platforms) to enhance mammal attraction and track identification (Foresman and Pearson 1998). However, the potential of these components to invoke attraction or aversion responses may also limit track-plate applicability for research that requires information on natural mammal movements.

Track-capture methods that detect mammals without influencing their natural movements can elucidate habitat-use patterns at smaller spatial scales

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more accurately than techniques that incorporate artificial components. For example, some carnivores have exhibited wariness to enter track-plate stations despite deployment of bait and scent lures (Gompper et al. 2006, Vanak and Gompper 2006). Although track-plate efficacy differs relative to platform and media types (Belant 2003, Wemmer et al. 1996), *Procyon lotor* (Raccoon) demonstrated reluctance to step on artificial platforms (Wolf et al. 2003) and the lack of platforms altogether has increased visitation rates for foxes (Sargeant et al. 2003). Snowtracking evades these issues and captures tracks from natural mammal movements by avoiding artificial components; however; its use is restricted to snow-covered regions (Gompper et al. 2006). Sand or raked-soil track plots are plausible alternatives because they capture tracks more naturally (Bider 1968). However, their ability to register identifiable mammal tracks may be unreliable (Glen and Dickman 2003), without mineral oil (Kuehl and Clark 2002, Renfrew et al. 2005), and albeit untested, some mammals may exhibit wariness of sand where it represents a foreign edaphic substrate. Hence, a technique that detects mammal presence with minimal bias should avoid using artificial or foreign components whenever possible.

We propose mud track plots, which use natural ground substrates in an area cleared of debris to capture tracks, as an inexpensive technique to detect mammals. Furthermore, this approach to track capture avoids use of bait, foreign substrates, or platforms, thus reducing potential sources of movement bias. The performance of mud track plots was evaluated based on criteria that includes 1) implementation effort, 2) cost, 3) species detection, 4) proportion of plots to capture tracks in ≤3 days, and 5) species identification (Foresman and Pearson 1998). We predict that properly employed mud track plots will detect mammal occupancy under natural movement conditions.

Methods

Study site

We conducted this study intermittently from May–July, 2004 on a soybean (*Glycine* sp.) and cotton (*Gossypium* sp.) row-crop production farm in Sunflower County, MS, located in the Mississippi Alluvial Valley (MAV) physiographic region. The study area (33°20'N, 90°40'W; approximately 615 ha) was representative of the MAV landscape, being dominated by large (89.6 ± 15.7 ha), row-crop agricultural fields fragmented by wooded fencerows and linear riparian zones (i.e., streams, rivers, drainage ditches) with negligible topographic relief. Mud track plots were established immediately adjacent to 10-m wide, herbaceous strips juxtaposed to a wooded fencerow with an embedded drainage ditch (Conover et al. 2007). The ground substrate in the MAV was hard when dry, though softened considerably with moderate rainfall. Soil associations were mostly Dundee silt loam or Forestdale silt loam, which are stratified alluvium soils of fine to coarse texture with poor to moderate drainage (Powell et al. 1952). Daily precipitation measurements were obtained from the nearby (<25 km) US Department of Agriculture weather station at Beasley Lake, MS.

Mud track plots

Our mud track plots were a 1-m^2 region cleared of all vegetation and litter, such that only bare ground was exposed. We evaluated implementation effort and cost to establish, maintain, and monitor these plots based on equipment and manual labor requirements. We established mud track plots by first removing standing vegetation in a pre-measured plot, then scraping the dry ground with the flat side of a hand shovel to eliminate residual vegetation and grade the surface to maximize track detail. We wore gloves and rubber boots during plot preparation to minimize anthropogenic cues that may influence mammal behavior. Ensuing litter piles were removed to avoid obstructing the natural travel pathway of mammals; however, surrounding vegetation remained intact. We established 46 mud track plots during early May of 2004. Plots were re-scraped between data collection periods and otherwise every ten days to prevent track recounts and suppress vegetative growth to ensure the capture of clean track imprints under appropriate conditions. The 46 mud track plots were established in a paired design such that plots were in 23 adjacent sites at 50-m intervals, and located on opposite edges of 10-m wide herbaceous habitat strips. The ability of ground substrates to capture track detail depended on a suitable combination of precipitation and drying time. We determined mud track plot viability on post-rainfall mornings by the presence of identifiable mammal tracks or using finger imprints to test plot texture. As precipitation can vary locally in the MAV, all mud track plots were located within 3.5 km to maximize track plot viability in isolated precipitation events.

Track capture

We collected track data during four distinct periods (1–3 nights per period) that followed precipitation events of >1.0 cm. We evaluated the species-detection criteria by comparing medium- and large-sized mammals (>800 g) detected by track plots with mammals confirmed to be present through opportunistic sightings on the farm from May–July over three years (2002–2004). We measured the proportion of plots that captured tracks per tracking period to evaluate potential mammal wariness toward mud track plots. Other studies commonly recorded an average latency-to-first-detection of >3 days for mustelids and as such, we expected to capture few tracks in <2 days if mammals exhibit wariness (Foresman and Pearson 1998, Zielinski 1995). This effect is particularly relevant for mammals with previously documented wariness (e.g., Raccoons, foxes; Sargeant et al. 2003, Wolf et al. 2003). As we combined our data per tracking period, we report proportion of viable plots to capture tracks for 1-, 2-, and 3-day tracking periods.

Tracks were not recorded when plots received precipitation at night to prevent raindrops from effacing track detail. To minimize observer bias, one individual trained on track identification monitored all mud track plots on post-rainfall mornings. Pad measurements and photographs were initially used to confirm species identifications from track imprints (Murie 1954). We report track data as the number of detections/track plot-night for all mammal species. Track plot-night is defined as the number of viable mud track plots per night for all nights in a tracking period. If a track plot was unviable, it was removed from the track plot sample.

Results

One person established 46-mud track plots in two half-days, with individual plots being established in approximately 3–15 minutes/plot, dependent on the amount of vegetation removal required. Maintenance and monitoring commenced either post-track capture or every ten days, and temporal effort was approximately 1–5 minutes/plot, dependent on track detail and not including travel time. Costs were limited to the manual labor required to establish, maintain, and monitor track plots of a desired sample, as well as necessary materials (i.e., hand shovel, work gloves, boots).

Throughout the study, mud track plots received enough precipitation to collect data on at least four distinct occasions (8 total nights), including 28 May (1.07-cm precipitation on previous day), 04–06 June (4.1-cm precipitation on previous five days), 29–30 June (17.20-cm precipitation on previous five days), and 16–17 July (3.4-cm precipitation on previous day) 2004. However, we did not monitor plots during every potential opportunity (i.e., precipitation event) from May–July. The edaphic conditions at our study site were such that 1.07 cm of precipitation was sufficient to capture identifiable tracks of medium- and large-sized mammals for one night. A two-night data collection period (29–30 June) that was preceded by 17.20-cm of precipitation over five days rendered four of forty-six track plots (8.7%) unviable from standing water. Mud track plots captured identifiable tracks between 1–3 nights per data collection period, which depended on plot texture relative to total precipitation and drying time (e.g., cloud cover).

Species detection was considered robust because track plots detected all medium- and large-sized mammals previously confirmed on the study farm (Table 1). *Odocoileus virginianus* (White-tailed Deer), *Dasypus novemcinctus* (Nine-banded Armadillo), Raccoon, and *Canis latrans* (Coyote) (30, 19, 10, and 10%, respectively) were the most frequently detected species (Table 1). Eighty-five percent of mud track plots successfully recorded tracks at least once across the study. Using data combined across tracking periods, the proportion of viable plots that captured tracks included 15% in one night (28 May), 78% in three nights (04–06 June), 81% in two nights (29–30 June), and 74% in two nights (16–17 July). Mud track plots captured a total of 104 tracks for at least 11 mammal species (Table 1). Medium- and large-sized mammals produced descriptive track impressions. We identified all medium- and large-sized mammal tracks except one (100 and 98%, respectively), which was speculated to be a large *Canis familiaris* L. (Domestic Dog). We failed to distinguish tracks between *Sylvilagus floridanus* Allen (Eastern Cottontail) and *Sylvilagus aquaticus* Bachman (Swamp Rabbit) or *Sciurus carolinensis* Gmelin (Gray Squirrel) and *Sciurus niger* Linnaeus (Fox Squirrel), thus recorded them to genus. Small mammals only represented 5% of visible tracks, of which none were identified to species (Table 1).

Discussion

We evaluated mud track plot efficacy using implementation effort, cost, species detection, proportion of plots to capture tracks, and species identification (Foresman and Pearson 1998). Implementation effort for this technique was minimal during establishment, maintenance, and monitoring aspects of application. Initial establishment of 46 plots only required two half-days by one person. Although establishment effort will vary with geography and edaphic conditions, this technique has potential for application of large samples with a relatively nominal time requirement. Maintenance and monitoring effort depends on plot texture, surface damage, vegetative growth, and observer track-identification skills. We maintained plots after they had dried to prevent accidental recounts during subsequent tracking periods; however, preliminary plot re-scraping prior to drying (after recording track data) facilitated easier smoothing of dried plots. Many plots required no maintenance between precipitation events from lack of surface damage or vegetative growth. As mud track plots required minimal equipment, the primary costs will be manual labor, which is relative to the desired plot sample.

All mammal species documented on the study farm over 3 summers (2002–2004) were detected by mud track plots, excepting small mammals (e.g., mice), sciurids, and lagomorphs due to difficulty in distinguishing species from tracks. Our three-year, mammal inventory was relatively comprehensive as determined by repeat sightings of every species. We acknowledge this species list may be incomplete as it was a product of opportunistic observation and not an intensive, systematic survey. However, our study farm was also conducive for visual documentation from a paucity of vegetative cover and mammal diversity. Furthermore, we did not detect any species on our mud track plots that had

Table 1. Mammal tracks recorded using mud track plots to survey mammal species' occurrence on edges of herbaceous strip habitats in the Mississippi Alluvial Valley during 2004. TD = total detections; May= 28 May; June1 = 4–6 June; June2 = 29–30 June; July = 16–17 July.

Mammal species	TD	May	%[A]	June1	%	June2	%	July	%
White-tailed Deer (*Odocoileus virginianus* Zimmermann)	31	1	0.022	9	0.065	9	0.107	12	0.130
Nine-banded Armadillo (*Dasypus novemcinctus* Linnaeus)	20	2	0.043	5	0.036	9	0.107	4	0.043
Raccoon (*Procyon lotor* Linnaeus)	10	1	0.022	2	0.014	5	0.060	2	0.022
Coyote (*Canis latrans* Say)	10	1	0.022	5	0.036	3	0.036	1	0.011
Red Fox (*Vulpes vulpes* Linnaeus)	7	0	0.000	1	0.007	2	0.024	4	0.043
Bobcat (*Lynx rufus* Schreber)	5	2	0.043	0	0.000	2	0.024	1	0.011
Opossum (*Didelphis virginiana* Kerr)	5	0	0.000	2	0.014	1	0.012	2	0.022
Squirrel (*Sciurus* spp.)	4	0	0.000	3	0.022	1	0.012	0	0.000
Feral Cat (*Felis silvestris* Schreber)	3	0	0.000	2	0.014	1	0.012	0	0.000
Striped Skunk (*Mephitis mephitis* Schreber)	2	0	0.000	1	0.007	0	0.000	1	0.011
Rabbit (*Sylvilagus* spp.)	1	0	0.000	0	0.000	1	0.012	0	0.000
Small mammals	6	2		2		0		2	

[A]Proportion of detections per species relative to number of viable mud track plot-nights in data collection period.

not been previously identified in the study area. Maximum species detection in other studies may be facilitated by appropriate track plot placement (e.g., natural corridors, diverse habitats). The success with which mud track plots quantified species richness for medium- and large-sized mammals supports previous findings of track census accuracy (Silveira et al. 2003).

Our mud track plots captured mammal tracks on the first night of adequate substrate texture. First night detections included Raccoons and second-night detections included Red Foxes, which are both species known to exhibit wariness of other track capture methods (Sargeant et al. 2003, Wolf et al. 2003). We speculate that failure of some plots to capture tracks during the first night may have resulted from lack of mammal activity in that particular area. The immediacy of mud track plot detection viability supports the idea that mammals exhibit reduced wariness toward track plots of natural substrates than track-capture techniques with foreign components (Zielinski 1995). The majority (74–81%) of plots captured tracks during two and three-night periods, which may be associated with the duration of rainfall (e.g., 5 days) prior to track capture, although this is untested. We are unaware of any studies that report aversion of wild mammals to step on mud substrates. Furthermore, the ability of these plots to capture tracks immediately (i.e., first night) suggests equal detectability across tracking-period length, and therefore, data would be comparable in either a three-night period or three 1-night tracking periods. Hence, we predict applicability of mud track plots for study areas and seasons with broad ranges of precipitation events.

Mud track plots captured identifiable tracks of medium- and large-sized mammals, yielding information on species occurrence. Track plots were viable after a minimum of 1.0 cm precipitation, depending on plot texture. Duration of track-plot viability depended on amount of precipitation and drying time (e.g., cloud cover). This variability is exemplified by a 14.2-cm precipitation event (over 5 days) that only facilitated two viable nights of track capture before desiccation occurred from extreme heat, whereas a 4.1-cm precipitation event (over 5 days) followed by mild temperatures and greater cloud cover captured tracks for three-nights. The intense heat in the MAV may reduce duration of track plot viability from desiccation relative to other areas. Furthermore, we also recorded a one-day 3.4-cm precipitation event that may have permitted more than two-nights of track capture, but the data collection ended prematurely from additional heavy rainfall. Alternatively, we acknowledge the potential value of mild precipitation during track capture periods to maintain plot saturation, although caution should be used to avoid track imprint effacement. Furthermore, study areas with more frequent precipitation may allow more consistent track plot employment. While the lucid detail of most pad impressions often permitted quick, accurate track identification (Murie 1954), there is potential for difficulty in identifying species by tracks to limit the applicability of this technique, particularly in areas where species with similar tracks co-occur (Zielinski and Truex 1995). Although the majority of mammals on our study farm had relatively distinguishable tracks, the possibility of misidentification exists between species with similar tracks (e.g., Red Fox and young Coyote).

Additional limitations associated with mud track plots include 1) difficulty to detect and/or identify tracks of small mammals, 2) temporal unpredictability from precipitation dependence, and 3) spatial restrictions from isolated precipitation events. The under-representation of small mammals was not surprising, as difficulties in capturing and identifying small mammal tracks have been previously reported (Wemmer et al. 1996). Although the dependence of mud track plots on precipitation may preclude interpreting resultant data as absolute values, they remain viable estimates for relative comparisons. The precipitation dependence of mud track plots may be circumvented using manual water saturation; however, this remains untested. Future studies should investigate applying mud track plots in baited applications as potential replacements to tracking platforms.

According to Foresman and Pearson's (1998) criteria to evaluate technique efficacy, mud track plots performed effectively to detect occupancy of medium- and large-sized mammals. The success of this technique is attributed to their minimal cost and effort, high proportion of plots that captured tracks in 1–3 days, having recorded all visually confirmed mammal species in the study area, and capturing identifiable (≥98%) track imprints. Given the variety of mammalian survey approaches, technique selection should be based on research objectives and method applicability (Foresman and Pearson 1998, Mowat et al. 2000, Wolf et al. 2003). We advocate the use of mud track plots for spatially explicit habitat-use investigations of medium- and large-sized mammals to detect presence-absence with minimal bias of natural movements.

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