Spatial and Behavioral Dynamics of Socially Isolated Wild Pigs Following Sounder Removal

by

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Abstract

Effective management of invasive wild pigs (*Sus scrofa*) requires understanding how individuals respond to social disruption. We GPS-collared 18 female wild pigs to evaluate spatial behavioral changes following partial sounder removal via trapping. Over a 30-day post-trapping period, pigs remained close to trap sites (mean: 1.2 km; max: 6.4 km), showed stable range sizes, and limited dispersal. Using net squared displacement modeling, we classified daily movement into six behavioral strategies and evaluated time allocation as well as the influence of social structure and composition. Wild pigs showed a clear temporal progression from structured, cautious behaviors (encamped, semi-roundtrips) to unstructured, more flexible behaviors (wandering, exploring), with a transition occurring around days 18-20. Lone pigs were influenced by social composition: individuals from adult- and female-rich sounders initially exhibited strong site fidelity following trapping but gradually shifted towards more exploratory behaviors over time. These results suggest that lone survivors often remain in or return to trap site areas, creating a critical window for follow-up efforts. Understanding spatial behavior after disturbance can improve control strategies and reduce the risk of disease spread.

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Chapter 1: Spatial behavior of isolated wild pigs following sounder removal via trapping

Abstract

The rapid expansion of wild pig populations across North America, along with emerging global disease threats, has created a need for effective management strategies to reduce environmental impact and prevent disease spread. While trapping is regarded as the most effective method for controlling wild pigs, the extent to which trapping disrupts sounders and affects individual pig behavior remains unclear. Specifically, missed trapping events may result in changes in behaviors by untrapped individuals, potentially undermining management efforts. We evaluated the spatiotemporal behavior of wild pigs that were separated from their sounder during trapping events. We deployed GPS collars on 18 female wild pigs from different sounders and evaluated distance traveled from the trap site, step length, persistence velocity, space covered, and overlap area following trapping events. Our results showed high variability among individuals, but overall trends indicated wild pigs travelled on average 1.2 km, with a maximum observed distance of 6.37 km over a 30-day post-trapping period. We observed limited overlap of space use and stable range sizes. Wild pigs from sounders with a greater proportion of females moved further away from the trap, and those in better condition moved slower. Our findings suggest that wild pigs stay close to the trap site after a trapping event, rarely leaving the area. This behavior provides sufficient time for trapping programs to effectively target untrapped individuals and enhance management outcomes.

Introduction

The wild pig (*Sus scrofa*), a successful invasive species in North America and other continents, has garnered significant attention in the United States in recent decades due to the accelerated rate at which it has expanded its range. As a result, substantial effort has been directed at developing management practices and tools to decrease environmental impacts (Bengsen et al. 2014; Wehr et al. 2018; VerCauteren et al. 2024), reduce population densities (Lewis et al. 2019), and mitigate the spread of diseases that could impact livestock, wildlife, and humans (Barrios-Garcia and Ballari 2012; Bevins et al. 2014). The potential for wild pigs to spread foreign animal diseases has always been a concern, but it has increased recently due to the

rapid spread of African Swine Fever (ASF) in wild swine populations in Europe and other areas (Sauter-Louis et al. 2021; Mighell and Ward 2021).

Although management of wild pigs involves a variety of tools and techniques to reduce their impacts, most efforts are focused on density reduction, and trapping is the primary form of population control employed across most of their range (VerCauteren et al. 2019). Most successful trapping programs incorporate some form of removal strategy (Ditchkoff and Bodenchuk 2019), with Whole Sounder Removal (WSR) being the strategy that has garnered the most attention. Recent studies have demonstrated that WSR can significantly reduce wild pig numbers, especially in areas where wild pigs exhibit high site fidelity (Bastille-Rousseau et al. 2021; Lewis et al. 2022; Kilgo et al. 2023). However, the success of such programs in North America have been inconsistent, perhaps indicating that sustained and long-term efforts are essential for reducing populations (Garabedian and Kilgo 2024). Additionally, the spatial and social dynamics of wild pigs complicate the effectiveness of WSR. Although sounders are generally cohesive, individual pigs may exhibit behaviors such as temporarily splitting from the group, shifting home ranges, or overlapping with other sounders (Boitani et al. 1994). These patterns increase the likelihood of partial removals, specifically in areas with complex landscapes or dense cover, where pigs can evade traps. As a result, even targeted efforts may leave behind untrapped individuals, who can rapidly recolonize and compromise control programs (Bastille-Rousseau et al. 2021).

When implementing WSR strategies to manage wild pig populations, there is potential disruption to sounders. For instance, trapping may not capture all individuals within the sounder, despite efforts to do so, leading to possible compensatory responses by untrapped individuals. Limited research suggests that when some members of a sounder are trapped and removed, the behavior of the remaining, untrapped individuals may shift in response. Such social disruption can lead to changes in home range size (Bastille-Rousseau et al. 2021) or a tendency for pigs to remain closer together, thereby reducing group dispersion (Keuling et al. 2010). Further, recent research suggests that social interactions are more important than land cover variables to movement behavior of wild pigs (Ellison et al. 2024); thus, effects of trapping on movement behavior could be impacted by social structure. Given the role social structure poses on wild pig

behavior, understanding social disruption is crucial for improving trapping strategies, particularly during disease emergencies such as the introduction of ASF.

Our goal was to evaluate the effect of trapping on spatiotemporal behavior of wild pigs. Specifically, we focused on the behavioral responses of individual wild pigs that remained after the rest of their sounder had been euthanized during trapping. We examined key movement metrics—such as distance traveled from the trap, step length, persistence velocity, space covered, and overlap proportion of area after the trapping events—to determine if they changed over time following the trapping event. Understanding temporal variation in these metrics is important because wild pigs may exhibit immediate behavioral responses to social disruption that fluctuate over time. These dynamics can influence the timing and effectiveness of follow-up management efforts, especially during disease emergencies when the risk of spread may vary depending on when pigs resume routine movements. By quantifying these patterns, we aim to improve predictions of post-trapping space use and assess how behavioral recovery may affect the success of control programs targeting disease outbreaks.

Material & Methods

Study Area

The research took place on three study sites encompassing five counties (Bullock, Dale, Geneva, Henry, and Russell) in Alabama, USA (Figure 1.1A). All properties within the study areas were selected due to their participation in the USDA Natural Resources Conservation Service's Feral Swine Eradication and Control Pilot Program (USDA 2018) and/or because they were cooperators with USDA Wildlife Services. All study sites were in the coastal plain region of Alabama, and the landscape at all study sites was characterized by a combination of agricultural areas, mixed forest, and wetlands. Vegetation in these regions was primarily composed of loblolly (*Pinus taeda*), slash (*P. elliottii*), longleaf (*P. palustris*), and shortleaf pine (*P. echinata*), interspersed with occasional patches of hardwoods. Elevation among study areas ranged from 103.63-201.16 m; average temperature was 19.2 °C ranging from 11.7°-26.2 °C, and annual precipitation was 2.74 m (NOAA 2024).

Data Collection

From 22 February 2022 to 1 March 2023, we conducted opportunistic wild pig captures using corral traps baited with whole kernel corn (Figure 1.1B) with the aim of capturing different sounders throughout the study sites. Once sounders were located, corral traps were assembled on site and consisted of five panels (each 4.9-meter in length) secured with 1.6-meter t-posts firmly anchored into the ground on the exterior. Panels were positioned with a 0.5-meter overlap and affixed to t-posts using baling wire. Two types of trap doors were employed. At most sites, we used a 2.4-meter guillotine-style M.I.N.E.™ Gate (Jager Pro, Fortson, GA, USA) triggered remotely by an observer monitoring live footage from a M.I.N.E.™ Cam system (Jager Pro, Fortson, GA, USA) between 1700 and 0600. In other locations, we deployed traditional trip-wire triggered guillotine doors. These traps used a tensioned wire suspended 40-50 cm above ground level across the rear section of the trap, designed to be triggered by adult wild pigs exerting pressure on the line. This design minimized premature activation by smaller pigs or non-target species. Wild pigs were allowed to acclimate to the trap until the entire sounder reliably entered the trap. Once the entire sounder was consistently inside the trap, the gate was either remotely closed by an observer or, in the case of the trip-wire guillotine design, set the evening prior to allowing wild pigs to trigger it themselves.

After capture of the sounder, we randomly selected one female adult wild pig (*ca*. 40 kg) and affixed it with a Telonics® GPS/Iridium satellite transmitting collar (Iridium collars TGW-4470-4, Telonics Inc.). We focused only on females in this experiment because they are generally the target for wild pig control programs (USDA APHIS 2015). To attach the collar, we isolated the selected wild pig from the rest of the sounder then blindfolded and immobilized it using lassos to reduce stress without the use of sedatives or anesthesia. We collared only one individual wild pig per sounder. We programmed the GPS collars to collect and store locations every 15 minutes for real-time monitoring. Drop-off mechanisms were programmed to automatically release the collars 180 days after deployment, after which we retrieved the collars and downloaded the full location datasets. After collaring, we released the selected pig from the corral trap and euthanized the remaining wild pigs within the sounder. We recorded sounder size

and composition (males/females; adults/juveniles) and measured chest girth and body length of both the collared wild pigs and other sounder members (following Kruis et al. 2024)

We carried out trapping efforts with the assistance of USDA APHIS Wildlife Services collaborators. Prior to data collection, collaborators requested that landowners and hunters refrain from targeting our selected wild pigs. However, landowners and hunters were permitted to remove other wild pigs at their discretion as part of normal operations. None of the study areas had been trapped previously by Wildlife Services, but wild pigs in these areas faced pressure from sporadic trapping, shooting, and hunting with dogs. We conducted all capture and handling procedures under approval from the Institutional Animal Care and Use Committee (IACUC) at Auburn University under folio PRN 2022-4026.

Spatial Movement Metrics

We cleaned spatial data from GPS-collared wild pigs by removing erroneous fixed locations and duplicates. We established the final recorded locations as either the first mortality signal received from the collar (if deceased) or the programmed release time of the collar. For each individual, we examined daily variability in five spatial movement metrics following release from the trap: 1) distance from the trap, 2) step length, 3) persistence velocity, 4) space covered, and 5) overlap area. We selected these spatial metrics based on their demonstrated utility as behavioral indicators—previously used in other taxa—that could be displayed by wild pigs following a trapping event under the context of its movement ecology (Morelle et al. 2015). Each metric captures a distinct behavioral dimension. Distance from the trap reflects attraction or aversion to the site of capture and may indicate immediate avoidance behavior (*e.g.,* Bakaloudis et al. 2024). Step length is used as an indicator to assess the spatial displacement of individuals, revealing changes in movement efficiency or caution (*e.g.,* Suraci et al. 2019). Persistence velocity integrates both speed and directional consistency, thereby distinguishing between straight, goal-oriented movements and short, localized movements (*e.g.,* Gurarie et al. 2009; González et al. 2017). Space covered represents the daily extent of area used and can signal exploratory movements or range contractions (*e.g.,* Snow and VerCauteren 2019). Overlap of area evaluates day-to-day similarity in space use; greater overlap suggests stability

and site fidelity (Kilgo et al. 2021), whereas reduced overlap may indicate behavioral displacement (Frey and Conover 2007). Together, these metrics offer complementary insights into how wild pigs adjust their movement patterns following partial sounder removal. All analyses were conducted in R version 4.3.2 (R Core Team 2023).

We calculated distance from the trap as the straight-line distance for each GPS point recorded and the trap location where each wild pig was captured. Step length was calculated as the linear distance between consecutive GPS points, representing individual displacement rates. Persistence velocity (*Vp*) was calculated using the following equation: $V_p(T_i) = V(T_i)\cos(\theta(T_i))$, where T_i represents each time observation, $V(T_i)$ represents the scalar speed (*i.e.,* magnitude of the velocity vector) at time T_i, and $\theta(T_i)$ is the angle between the velocity and a reference direction at that time. Turning angles (θ) were calculated using the lag function (Team et al. 2018). Persistence velocity (*Vp*) captures the tendency and magnitude of a movement to persist in a given direction (described by Gurarie 2013) and was scaled to meters per day (m/day) to reflect overall directional persistence in movement. Greater values represent more directed and efficient movement patterns—such as dispersal or relocation—whereas lesser values indicate more frequent directional changes, typically reflecting foraging or localized searching movement patterns.

We calculated space covered as the total ground area used by wild pigs at a daily scale following release from the trap, using autocorrelated kernel density estimation (AKDE) via the ctmm package (Calabrese et al. 2016). The AKDE accounts for the spatial and temporal autocorrelation in movement data (*i.e.,* repeated observations of the same pig) when developing an estimate of the space used by that pig (Fleming et al. 2015). We selected initial autocorrelation parameters from the variograms of each individual wild pig using the guess() function, then used the ctmm.select() function to fit suitable models via maximum likelihood. We compared those models using AIC values and used the most parsimonious model to estimate the total ground area used by the pig with a 95% Utilization Distribution (UD). We calculated the overlap proportion across six fixed time periods (days 1, 5, 10, 15, 20, and 30) using 15 pairwise comparisons (*e.g.,* day 1 versus day 5, day 1 versus day 10, etc.). We computed 95%

UDs using the adehabitat package (Calenge 2006) and used the kerneloverlaphr() function with the "HR" index (Kernohan et al. 2001) to quantify spatial overlap.

Short-Term Temporal Variation Analysis

We used generalized linear mixed-effects models (GLMM; nlme package; Pinheiro et al. 2011) to examine changes over time in four of the spatial parameters (distance to trap, step length, persistence velocity, and space covered) over specific time points: days 1, 5, 10, 15, 20, and 30 post-trapping. Our GLMMs were built using one of the spatial parameters as the response variable and time points (treated as continuous variable) as fixed effects. Pig ID was included as a random effect in all models to account for individual variability in these spatial parameters. Because these time points were fixed and not collected as a daily time series, this analysis differs structurally from the continuous long-term models described below.

We assumed a normal distribution for distance from the trap, persistence velocity, and space covered, and a negative binomial distribution for step length. To identify the appropriate statistical distribution, we compared models that assumed normal, Poisson, and negative binomial for each response variable. We evaluated the fit of each model by comparing a chi-square test statistic from the original dataset (χ^*) to a distribution of chi-square statistics derived from 500 datasets generated via parametric bootstrapping from the fitted models. A model was considered to be a reasonable fit if χ^* did not fall within the upper or lower 0.025 quantiles of the simulated chi-square distribution (Davison and Hinkley 1997). This procedure was repeated to identify appropriate statistical distributions for every response variable.

We additionally performed a Kruskal-Wallis (K-W) test on each response variable to determine if there was a specific time frame where wild pigs drastically changed their spatial behavior after the trapping event. The K-W test is a non-parametric analysis of variance that evaluates differences based on ranks of the data to determine whether there are statistically significant differences between the six time points, assuming all wild pigs behave similarly. We chose this non-parametric test because not all pigs had data for all time points, resulting in low sample sizes for some comparisons.

We also used a K-W test to assess whether the proportion of area overlap differed significantly among the 15 combinations of time points described above. To further explore temporal patterns in spatial consistency, we implemented a logistic regression model to estimate the probability of overlap exceeding a specified threshold (>30%) at all time points. This threshold was selected based on previous studies of wild pig territoriality (Sparklin et al. 2009) and space-use overlap (Schlichting et al. 2022), which identified 30% as a meaningful level of shared space use. Overlap values above this threshold have been interpreted as indicative of spatial fidelity or reuse, whereas lower values may reflect avoidance or shifting home ranges. Because spatial overlap is a pairwise, non-continuous measure that was calculated across the specific time-point combinations rather than daily, it was analyzed separately from the four continuous daily movement metrics. We created a binary response variable for each pairwise comparison (1 = overlap $\geq$ 0.3; 0 = overlap $\leq$ 0.3). The logistic regression model was built using the binary variable as the response variable, Time 1 (6 levels), Time 2 (6 levels), and their interaction as fixed effects.

Social Structure and Long-Term Temporal Variation Analyses

Given that spatial overlap was modeled separately due to its pairwise and threshold-based structure, we restricted our long-term temporal variation and further analyses to the four continuous, daily resolved spatial parameters: distance to trap, step length, persistence velocity, and space covered. We used generalized linear-mixed effects models (GLMM; nlme package; Pinheiro et al. 2011) to examine the influence of social structure (*i.e.,* sounder size and composition) on the four continuous spatial parameters over extended periods following the trapping event. To complement our short-term analysis of the first 30 days post-trapping, we included the number of days since the trapping event as a continuous covariate to account for longer-term temporal variation. This allowed us to assess whether spatial parameters exhibited consistent increases or decreases over time across the entire post-trapping period (ranging from 7 to 138 days), as pigs recovered or re-established routine movement. Pig ID was included as a random effect to account for individual variability and to correct for the pseudoreplication that could arise from the number of days after trapping events. Appropriate statistical distributions

for each response variable were determined using the method described above. Given we were working with time series data (i.*e.,* data collected subsequently over time such as real-time tracking) we examined the residuals of our fitted models for temporal autocorrelation using the acf() function from the stats package (R Core Team 2023). Mixed models with temporal autocorrelations were updated by adding an autoregressive process of order 1 (corAR1) as a correlation structure argument (Box et al. 2015), and we evaluated model improvement by comparing models with and without the autoregressive residual process using the MuMin package (Barton and Barton 2015). Sounder size was defined as the total number of wild pigs in the sounder, excluding the collared wild pig. Sounder composition variables were the proportion of females and the proportion of adults in the sounder. We built GLMMs using one of the spatial parameters as response variables, and days after the trapping event (continuous), study sites (3 levels), sounder size (continuous), sounder composition (continuous), and the interaction between the proportion of females and adults as fixed variables. Interactions were removed when not statistically significant. We assessed the significance of predictor variables in each GLMM using a type II ANOVA, which adjusts for the presence of multifactor models with interactions (Smith and Cribbie 2014).

Body Condition Analysis

We used GLMMs to examine the effect of body condition of each collared wild pig on the same four spatial parameters described in the social structure analysis. Due to challenges during GPS collar fitting, only 78% of the wild pigs (*i.e.,* 14 pigs) were measured for chest girth and body length. Because longer pigs are likely to have larger chests, we calculated a body condition index as the residuals from a model that regressed chest girth on body length (Schulte-Hostedde et al. 2005). A positive residual indicates that a pig's body condition was better than the average pig of a similar body length, (*i.e.,* good condition), while a negative residual indicates a body condition worse than the average pig of a similar body length (*i.e.,* poor condition). Our GLMMs were built using spatial parameters as response variables, with the same fixed variables from the social structure analysis plus the body condition index included. We determined the appropriate statistical distribution for each GLMM and accounted for temporal autocorrelation as described above.

Results

We collared a total of 18 wild pigs from all study sites, with a mean tracking duration of 60.61 ± 10.40 days (mean ± SE), ranging from 7 to 138 days. Wild pigs had a mean of 4,678.61 ± 800.06 fixed points, with a range of 462 - 84,215 points. The daily mean was 77.33 ± 3.68 GPS points, ranging from 25 to 90 points per day. Wild pigs were separated from sounders ranging in size from 2 to 18 (8 ± 0.98), and sounders were comprised of 58.21% ± 6.06 females (0-100; min-max) and 38.34% ± 9.20 adults (0-100%) (Table 1.1).

Short-Term Temporal Variation

Across the 30-day post-trapping period, we found limited evidence that wild pig movement behavior changed substantially over time. The mean distance from the trap ranged from 0.51 to 4.28 km (Figure 1.2), with a mean of 1.27 km ± 0.22 SE (Table 1.2) after trapping events. Our linear mixed-effect model showed that for each 1-day increase in time, there was a 0.014 km (± 0.07 km, ± 95% C.I.) increase in distance from the trap (GLMM: $p = 0.011$; Table 3; Figure 1.3), although this effect was not reflected in comparisons among discrete time points (K-W: $p = 0.726$; Table 3; Figure 1.4). In contrast, we found no evidence of temporal change in step length (GLMM $_{\text{negative binomial}}$: $p = 0.957$), persistence velocity (GLMM: $p = 0.873$), or space covered (GLMM: $t_{18,77} = -1.17$, $p = 0.267$), and no significant differences across any of the six post-trapping time points (all K-W: $p > 0.60$). Spatial overlap remained low and stable (mean = 30.54% ± 1.60 SE; Table 1.2), with no differences among pairwise time combinations (K-W: $p = 0.635$). The probability of high overlap (i.e., >30%) remained below 5% throughout the post-trapping period and showed no significant change over time (GLMM $_{\text{binomial}}$: $p \geq 0.256$).

Social Structure Effects and Long-Term Temporal Trends

Long term temporal variation was assessed in wild pigs tracked from 7 to 138 days (4.5 months) post-trapping. Over time, spatial parameters generally declined: for each 1-day increase since capture, step length decreased by 0.24 m (± 0.06 m, ± 95% C.I.; GLMM: $p < 0.001$; Table

4), persistence velocity decreased by 9.82 m/day (± 2.67 m/day, ± 95% C.I.; GLMM: $p < 0.001$), and space covered declined by 0.006 km^2 (± 0.002 km^2, ± 95% C.I.; GLMM: $p < 0.001$). In contrast, distance from the trap did not show a significant temporal trend (GLMM: $p = 0.249$). Social structure further modulated these patterns. For each 10% increase in the proportion of females in a sounder, step length decreased by 4.88 m (± 0.39 m; ± 95% C.I; GLMM: $p = 0.007$; Table 4), and persistence velocity decreased by 238.47 m/day (±229.59 m/day; ± 95% C.I; GLMM: $p = 0.023$). The proportion of females also had a marginally positive effect on distance from the trap (0.21 km increase per 10%; ± 0.46 km, ± 95% C.I.; GLMM $p = 0.058$), while no social structure variables significantly influenced (GLMM: all $p \geq 0.215$) space covered after the trapping event.

Body Condition Effects

Body condition did not significantly influence distance from the trap (GLMM: $p = 0.949$; Table 5), step length (GLMM: $p = 0.123$), or space covered (GLMM: $p = 0.33$) following trapping events. However, for each 1-unit increase in body condition index, persistence velocity decreased by 67.11 m/day (± 66.18 m/day, ± 95% C.I.; GLMM: $p = 0.016$) after the trapping event. In addition, watershed identity significantly influenced space covered (GLMM: $p < 0.001$).

Discussion

We detected notable variability among wild pigs in their spatial patterns after trapping events. This variability was apparent with regards to distance travelled from the trap site, step length, rate of movement, and range size. Variability among individuals is common across many wildlife species (Merrick and Koprowski 2017; Stuber et al. 2022) from carnivores (Austin et al. 2004; Duncan et al. 2015) to ungulates (Singh et al. 2012; Bonnot et al. 2015) and can be influenced by various factors such as age, sex, personality traits, or environmental conditions (Dingemanse et al. 2010; Wolf and Weissing 2012; Singh et al. 2012; MacKay and Haskell 2015; Wat et al. 2020). Brogi et al. (2022) described individual variability in wild boar as reflecting distinct risk-taking syndromes where some individuals displayed strong site fidelity

and human avoidance and others compensated by selecting open habitats and demonstrating high mobility. These spatial behaviors, referred to as spatial personalities (Stuber et al. 2022), highlight how intraspecific differences in movement and habitat use can result from both intrinsic personality traits and environmental interactions, shaping their ability to adapt to exterior stimuli.

Approximately half (55%) of the wild pigs in our study stayed within 1.2 km of the trap site for the entire collaring period: the furthest any wild pigs moved following the trapping event was 6.37 km, and only three animals went further than 2 km from the trap site. These movements are notably constrained compared to wild pigs traveling in undisturbed sounders, which have been observed covering broader areas when foraging or migrating (Mayer and Brisbin 2008; Schlichting et al. 2016). Thus, these results suggest that a trapping event that isolates a wild pig from its sounder will likely not result in that individual leaving the area during the weeks following the event. Other studies with wild pigs have reported similar results. Maillard and Fournier (1995) and Choquenot et al. (1996) reported that pigs moved on average 1.8 km in the two weeks following the trapping event. Similarly, Sodeikat and Pohlmeyer (2003) documented that only 10% of pigs moved more than 2 km from the trap site after a drive hunt, with most returning to their central home range within 4 to 6 weeks. However, when exposed to other types of lethal disturbances, such as dog- or drive-hunting, wild pigs have been reported to travel over much greater distances, often exceeding 5 km, and sometimes as far as 9 km (Choquenot et al. 1996; Sodeikat and Pohlmeyer 2003).

Based on expectations drawn from other studies and field observations, we anticipated that wild pigs might exhibit long-distance movements immediately following the trapping event. However, on the first day following the trapping event, wild pigs in our study travelled distances ranging from 0.4 to 2.03 km. This is consistent with findings from other studies where piglets fled on average 2.2 km to available cover after live-trapping events (Sodeikat and Pohlmeyer 2004). Variation in flight distance may be influenced by the intensity of the disturbance, prior experiences, or the age (Gray et al. 2019). Moreover, long-distance travel during the 30-day window of our study was rare, with our maximum distance traveled in one day being 4.50 km. While previous research has reported that wild pigs may travel 18 km or more in a single day to

reach resource-rich areas associated with food, water, or other valuable resources (Pullar 1950; Conley et al. 1972; Mayer and Brisbin 2008; Hartley et al. 2015), our results suggest that trapping-related disturbance does not typically elicit short-term movements of that magnitude.

Although wild pigs in our study progressively increased their mean distance from the trap site during the 30 days following the trapping event, the mean daily increase (0.003 km) that we detected is not biologically significant (Mayer 2009). Singer et al. (1981) reported different results. They found that wild pigs tend to reduce distance travelled after minor disturbances, such as occasional hunting, with daily distances reduced from 0.6 km to 0.2 km after the disturbance. The limited increase in distance from the trap suggests that untrapped pigs may prioritize the benefits of staying within their home range (*e.g.,* access to known resources) over the risks associated with exploring new areas (Tobin et al. 2011; Bonte et al. 2012; Behr et al. 2020).

We did not document noticeably heightened activity levels in our wild pigs following the trapping event, which differed from our initial expectations. Instead, we observed relatively consistent movement rates throughout the 30-day period of interest—below 2 km/day. Although our results suggest a slight decrease in rate of movement over the long-term—declining by 9.82 m/day, this reduction does not represent a biologically relevant change in daily movement patterns (Gray et al. 2019). The observed movement rates align with wild pigs in eastern Australia, which moved at speeds of 2.8 km/day (Pech and McIlroy 1990), supporting the idea that after a trapping event, lone wild pigs do not engage in heightened levels of alertness or flight responses. To provide a more detailed comparison, we estimated the hourly movement rates for our wild pigs at approximately 0.09 km/h. Previous research has shown that speeds below 1 km/h are generally associated with routine behaviors—feeding, wallowing, exploring, and marking, while speeds exceeding 2 km/h are linked to escaping, excursions, and dispersal movements (Spitz and Janeau 1990; Mayer 2009; Bastille-Rousseau et al. 2021). Notably, wild pigs have been reported to move up to 5 km/h during active travel (Barrett 1978) and can reach speeds of up to 15 km/h when alarmed (Barrett 1971), though these greater speeds are more reflective of instantaneous speeds rather than sustained daily patterns.

We observed no significant changes in space use for wild pigs after the trapping event, as they continued to cover a similar range size throughout the entire sampling period. Although range size remained consistent, the location of the utilized space appeared to shift. Specifically, pairwise comparisons of daily range across the 30-day collaring period revealed low spatial overlap, with the probability of exceeding 30% overlap remaining low. This suggests that although pigs used a consistent amount of space, they did not reuse the exact same areas from day to day, indicating spatial reallocation rather than expansion. Since we do not have data on their space use prior to the trapping event, we could not determine whether the event caused a radical change in their use of space. Nonetheless, our study animals remained relatively consistent in the range size that they used after the trapping event. Over the 30-day period following the trapping events our wild pigs showed a mean space covered of 3.2 km^2. This range size estimate is generally less than what has been reported in previous studies where wild pigs did not experience any disturbance (Mayer 2009; Schlichting et al. 2016; Gray et al. 2019). Similar range sizes to ours have been reported in Georgia, USA (3.05 km^2), where that population had been exposed to both hunting and trapping (Sparklin et al. 2009). However, our range size estimates were considerably larger than other studies that also experienced a control event—between 0.3 and 1.5 km^2 (Diong 1982; Baber and Coblentz 1986; Coblentz and Baber 1987; McIlroy 1989; McIlroy and Saillard 1989). In Alabama, previous research showed that wild pigs under high hunting pressures during a collaring period of 1.4 to 3.5 months had an average range size of 2.7 km^2 , while those experiencing lower hunting pressure had range sizes nearly twice as large (4.03 km^2) (Gaston et al. 2008). Range sizes can be influenced by various abiotic factors such as latitude, vegetation, food availability, and water sources (Schlichting et al. 2016), which may explain some of the variation observed between our study and others.

Social structure of wild pigs, particularly the composition of sounders before separation, may influence spatial behavior after trapping events. We detected a positive association between percent females in the sounder and distance from the trap during the entire collaring period. Wild pigs are known to form female-led groups with strong social cohesion (McIlraith 2021), and females often influence movement patterns—possibly due to their role in seeking safer or resource-rich areas for their sounder (Ellison et al. 2024). Similar patterns have been observed in other socially structured species, such as elephants (*Loxodonta africana*) and giraffes (*Giraffa*

camelopardalis tippelskirchi), where matriarchs often lead group movement, especially during disturbance (Tarou et al. 2000; Douglas-Hamilton et al. 2006). Based on these dynamics, we anticipated that wild pigs from female-dominated sounders might remain closer to the trap site, maintaining spatial cohesion. However, our results showed the opposite: individuals from more female-dominated sounders tended to move farther from the trap Given the limited data on post-trapping spatial responses in female wild pigs, any firm conclusion regarding the cause of this pattern would be speculative. It remains possible that the influence of female leadership within the sounder could condition movement dynamics, but more research is needed to determine the underlying factors driving these behaviors.

We found a negative association between body condition and activity levels following the trapping event. Specifically, we observed that pigs in better condition exhibited slower velocities, with a decrease of 67.1 meters per day following the trapping event. Similarly, movement behavior in other species has been shown to vary based on resource availability and landscape configuration, which directly influence body condition. For example, Doherty et al. (2019) demonstrated that greater resource availability in linear remnants reduced activity area size and movement rates in eastern bearded dragons (*Pogona barbata*). In another study, moose (*Alces alces*) in poorer condition exhibited greater activity levels during stressful conditions compared to those in better condition (Van Beest and Milner 2013), although the animals in that study were not exposed to a stressful event like trapping. Previous studies on wild pigs have also shown that spatial behavior and activity are primarily driven by seasonal changes in food availability, with individuals accustomed to reliable food sources tending to exhibit less activity (Podgórski et al. 2013).

Conclusion

Our data suggest that the risk of an infected pig, isolated from its original sounder and leaving the area to infect other animals, appears to be low. Despite some individual differences, most wild pigs did not travel far from the trap site during the 30-day period following a trapping event. Their movement rates remained slow, and spatial metrics consistent, indicating minimal disruption to spatial parameters. This stability reduces the likelihood of disease spread at a

population level under trapping conditions. However, spatial behavior can vary depending on latitude (Clontz et al. 2022), behavioral context, and sounder structure. For instance, in areas where wild pigs exhibit territorial behavior (Sparklin et al. 2009; Kilgo et al. 2021; Schlichting et al. 2022), disease transmission risk is less than in regions where groups overlap extensively (Boitani et al. 1994; Gabor et al. 1999; Lewis et al. 2022). Lone wild pigs present a unique risk, as they may join new sounders even while remaining within the spatial limits of their original sounder, as observed in one instance during our study.

Undoubtedly, control efforts designed to eliminate wild pig populations in the case of a novel disease outbreak will likely incorporate whole sounder removal (Lewis et al. 2022), or other trapping strategies (Ditchkoff and Bodenchuk 2019) to maximize probability of success. However, it is highly likely that not every sounder will be trapped and euthanized in a single trapping effort. Our data suggest that management programs such as these will not be negatively impacted by such occurrences. Rather, our findings indicate that these efforts may be more effective than previously anticipated (Leslie et al. 2014). Wild pigs that remain isolated after trapping are likely to stay near the trap site, enabling managers to target them with continued trapping efforts. Our findings suggest that these occurrences will not overly hinder the success of management programs. As mentioned before, wild pigs remained ≤1.2 km of the trap site—a distance well within the effective range of modern trapping systems. Considering that traps can influence wild pig movements over an area of 8.87 km^2 (Davis et al. 2017), pigs left behind are likely to remain within range of the initial trap or nearby traps, increasing the likelihood of recaptures through sustained efforts.

It should be noted that our data are limited to females that are currently in a sounder. Space use of males that are associated with a sounder, yet are not trapped when the sounder is captured, remains an important area for further study. Male wild pigs are more likely to disperse widely (Truvé and Lemel 2003; VerCauteren et al. 2019), interact with multiple sounders (Brogi et al. 2022), and increase the risk of disease transmission over larger areas (Halasa et al. 2019; Taylor et al. 2021), particularly during active breeding periods (Comer and Mayer 2009). By contrast, female-led sounders exhibit high site fidelity (Kaminski et al. 2005) and limited dispersal, posing a lower immediate risk of spreading disease. However, the strong cohesion of

sounders may require expanded control zones for systematic removal. Managers should adapt trapping strategies to account for these behavioral differences, based on the structure and condition of the population.

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Tables and Figures

Table 1.1. Attribute data for each individual wild pig that was captured and fitted with a GPS collar in the state of Alabama, USA, 2022-2023.

Individual	Sounder size [a]	Sex proportion (F:M) [b]	Age proportion (A:J) [c]	Start GPS	End GPS	Time monitored [d]	# Fixed points
Pig 1	7	6:1	4:3	02/22/22	03/01/22	7	634
Pig 2	7	5:2	2:5	02/23/22	03/26/22	31	2552
Pig 3	2	2:0	1:1	02/24/22	04/29/22	64	4403
Pig 4	17	12:5	2:15	02/26/22	06/05/22	98	8523
Pig 5	10	6:4	3:7	03/18/22	06/22/22	84	7563
Pig 6	18	11:7	1:17	04/01/22	07/22/22	118	7961
Pig 7	4	1:3	4:0	09/09/22	12/03/22	85	7324
Pig 8	6	3:3	6:0	11/03/22	03/02/23	119	9361
Pig 9	6	5:1	2:4	06/28/22	07/22/22	24	2046
Pig 10	9	6:3	3:6	06/30/22	07/07/22	7	600
Pig 11	9	6:3	1:8	07/19/22	08/09/22	21	1310
Pig 12	11	5:6	1:10	09/27/22	02/12/23	138	9698
Pig 13	7	2:5	5:2	10/01/22	01/06/23	97	6845
Pig 14	4	4:0	2:2	10/18/22	01/23/23	97	7714
Pig 15	8	4:3	All adult	10/19/22	10/26/22	7	612
Pig 16	9	5:3	4:4	01/26/23	03/03/23	36	3254
Pig 17	6	3:2	0:5	01/26/23	03/07/23	40	3353
Pig 18	4	1:2	All adult	01/28/23	02/15/23	18	462

[a] Sounder size at the time of capture, representing the total number of pigs in the sounder, with the collared wild pig included.

[b] Proportion of females (F) and males (M) within the sounder to which the collared pig belonged.

[c] Proportion of adults (A) and juveniles (J) within the sounder to which the collared pig belonged.

[d] Total number of days the collared wild pig was monitored.

Table 1.2. Summary of spatial parameters calculated from all 18 wild pigs collared during trapping events in the state of Alabama, USA, 2022-2023.

Spatial parameter	Mean	95% CI	Min	Max	SD	SE
Distance from the trap (km)	1.27	0.46	0.51	4.28	0.92	0.22
Step length (m)	46.80	7.12	18.66	69.57	14.31	3.37
Persistence velocity (m/day) [a]	2164.94	436.44	38.87	3724.87	877.65	206.86
Space covered (km^2)	3.59	2.27	0.004	17.21	4.41	1.07
Overlap area (%)	30.54	12.1	0	100	22.59	1.60

[a] Persistence velocity represents speed adjusted for directional consistency, in meters per day (m/day), following Gurarie et al. 2013.

Table 1.3. Results of generalized mixed-effect models (GLMMs) and Kruskal-Wallis test (K-W) evaluating short-term spatial behavior of wild pigs during the first 30 days post-trapping in the state of Alabama, USA, 2022-2023.

Spatial parameter	GLMM				K-W [b]	
	Estimate (β)	Test statistic	SE	p-value	Chi-square (χ^2)	p-value
Distance from trap	0.014	t = 2.52	0.005	0.011	2.83	0.011
Step length	-0.0002	Z = -0.05	0.004	0.957	3.58	0.957
Persistence velocity	1.420	t = 0.15	8.953	0.873	2.94	0.873
Space covered	-0.045	t = -1.17	0.041	0.267	3.20	0.267
Overlap (%) [a]	-0.841 [c]	z ≤ 0.32	4.575	≥ 0.256	11.63	>0.256

[a] Overlap was modeled separately using logistic regression based on a 30% threshold.

[b] Degrees of freedom were 5 for all tests except the logistic regression model (df=14).

[c] Estimate refers to the intercept of the logistic regression model.

Table 1.4. Results of generalized mixed-effect models (GLMMs) testing the influence of time since capture (days) and social structure on wild pig spatial behavior following sounder removal in the state of Alabama, USA, 2022-2023.

[a] Spatial parameter	[c] Predictor	Estimate (β)	t-value	SE	p-value
[b] Distance from trap b	Days since trap	-1.029	-0.599	1.716	0.249
	Sounder size	0.097	1.426	0.068	0.153
	% Female	0.021	1.009	0.021	0.058
	% Adult	0.040	2.009	0.019	0.774
	%F * %A	-0.0006	-2.039	0.0003	0.041
Step length	Days since trap	-0.242	-7.205	0.033	<0.001
	Sounder size	-0.402	-0.391	1.030	0.695
	% Female	-0.488	-2.663	0.183	0.007
	% Adult	-0.217	-1.554	0.139	0.120
Persistence velocity	Days since trap	-9.826	-7.200	1.364	<0.001
	Sounder size	-89.783	-1.503	59.708	0.132
	% Female	-23.847	-2.263	10.537	0.023
	% Adult	-12.880	-1.624	7.928	0.104
Space covered	Days since trap	-0.006	-4.851	0.001	<0.001
	Sounder size	0.065	0.097	0.671	0.922
	% Female	-0.127	-1.091	0.117	0.275
	% Adult	0.007	0.089	0.086	0.928

[a] All GLMMs were fit a using a Gaussian distribution with individual ID as a random effect and a corAR1 autocorrelation structure.

[b] Only the model for distance from the trap retained the interaction between percentage of adults and females; in all other models, the interaction was excluded due to non-significance.

[c] Sounder size predictor represents the total number of pigs in the sounder, with the collared wild pig not included.

Table 1.5. Results from generalized mixed-effect models (GLMMs) testing the effect of body condition on wild pig movement behavior following sounder removal in the state of Alabama, USA, 2022-2023.

[a] Spatial parameter	b Body condition			
	Estimate (β)	t-value	SE	p-value
Distance from trap	-0.002	-0.063	0.039	0.949
Step length	-0.598	-1.538	0.388	0.123
Persistence velocity	-67.110	-2.397	27.990	0.016
Space covered	-0.260	-0.965	0.269	0.334

[a] All models were fit using a Gaussian distribution and included the same covariates as previous model, with body condition added as additional predictor.

[b] Body condition index was calculated as the residuals from a regression of chest girth on body length.

Figure 1.1. Spatial layout of wild pig study sites and trap set up. A) Map of southeastern Alabama showing five focal counties (Bullock, Russell, Dale, Henry, and Geneva) used for GPS-collar deployment on wild pigs between 2022-2023. Shaded areas indicate counties where wild pigs were GPS-collared following sounder removal events. Black stars mark approximate capture sites. B) Field photograph of the corral-style trap used for live captures of wild pigs, illustrating the guillotine-style door, panel configuration, and surrounding habitat.

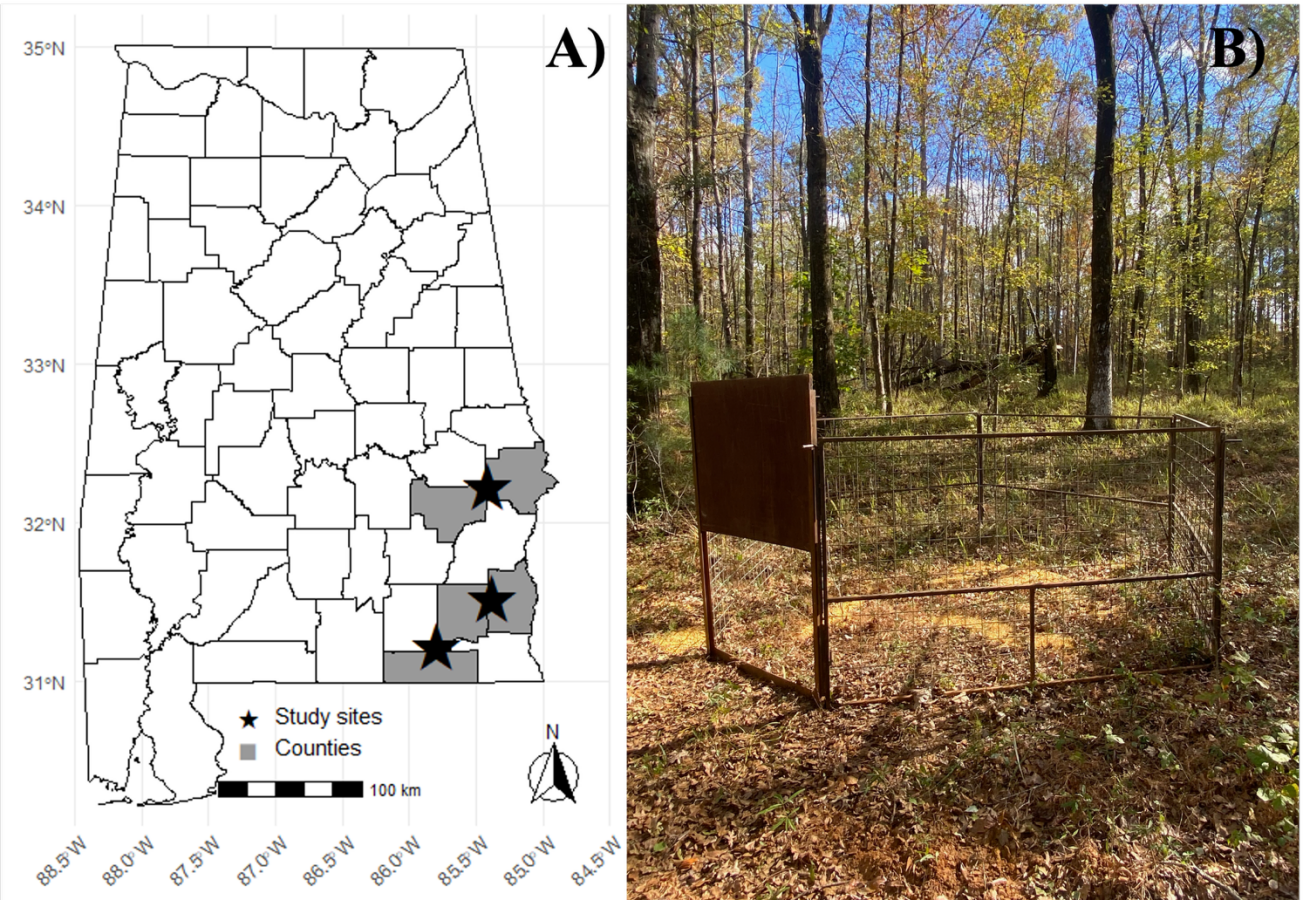


Figure 1.2. Mean (± 95% CI) values of five spatial parameter from each individual wild pig collared across their monitoring period. Dashed line indicates the overall population mean.

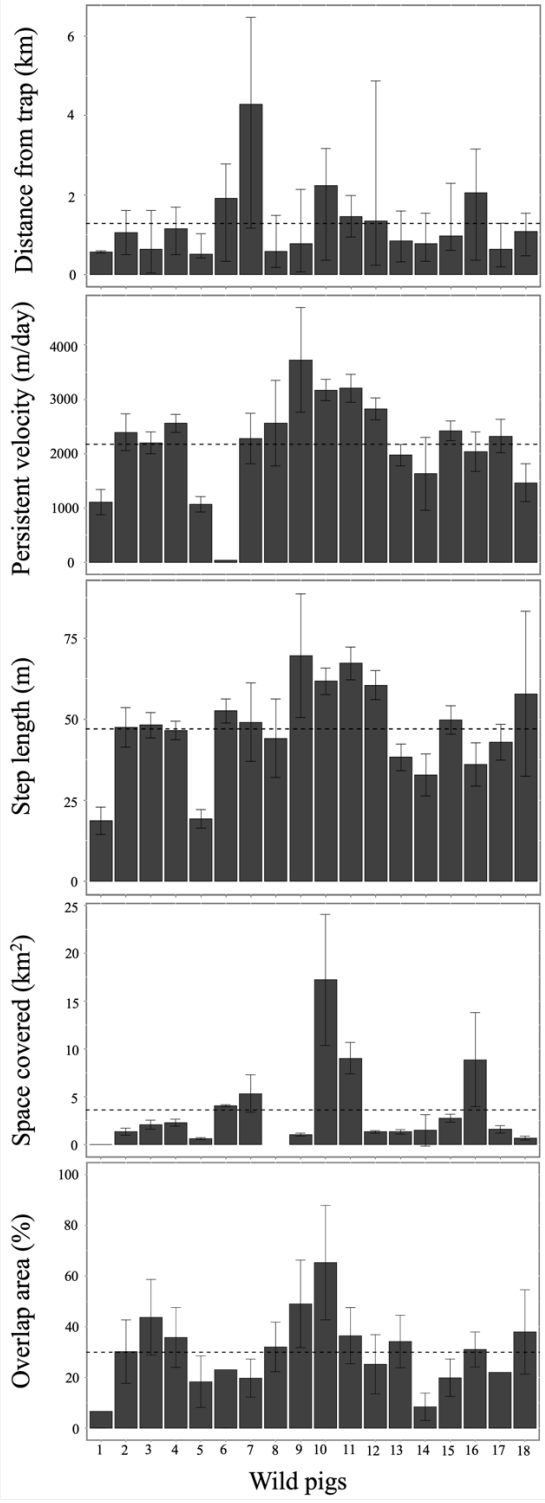


Figure 1.3. Temporal variation in distance from the trap site during the first 30 days following sounder removal for 18 GPS-collared wild pigs in the state of Alabama, USA, 2022-2023. Solid black line represents the fixed-effect predictions (± 95% confidence interval; shared area) from a generalized mixed-effect model for each spatial parameter: distance from trap (km), step length (m), persistence velocity (m/day), and space overlap (km^2). Light blue lines show individual pig trajectories. Equations in each panel indicate fixed-effect intercepts and slopes.

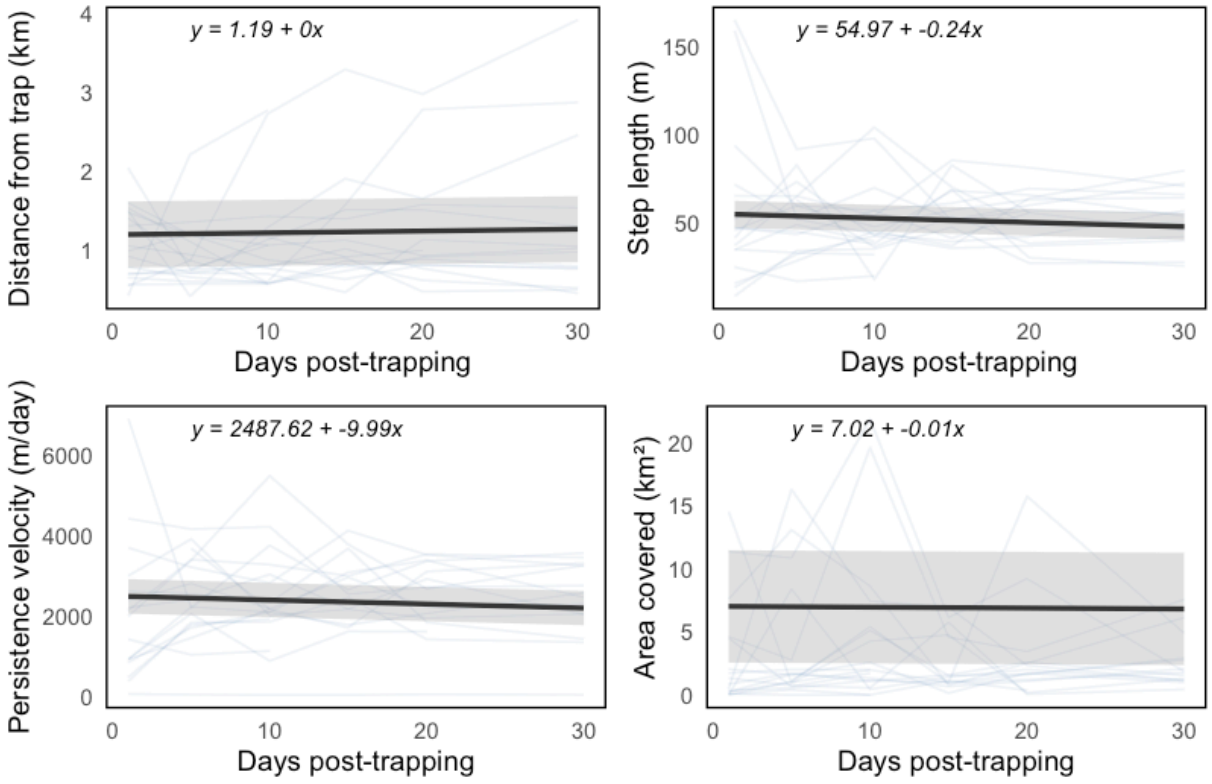
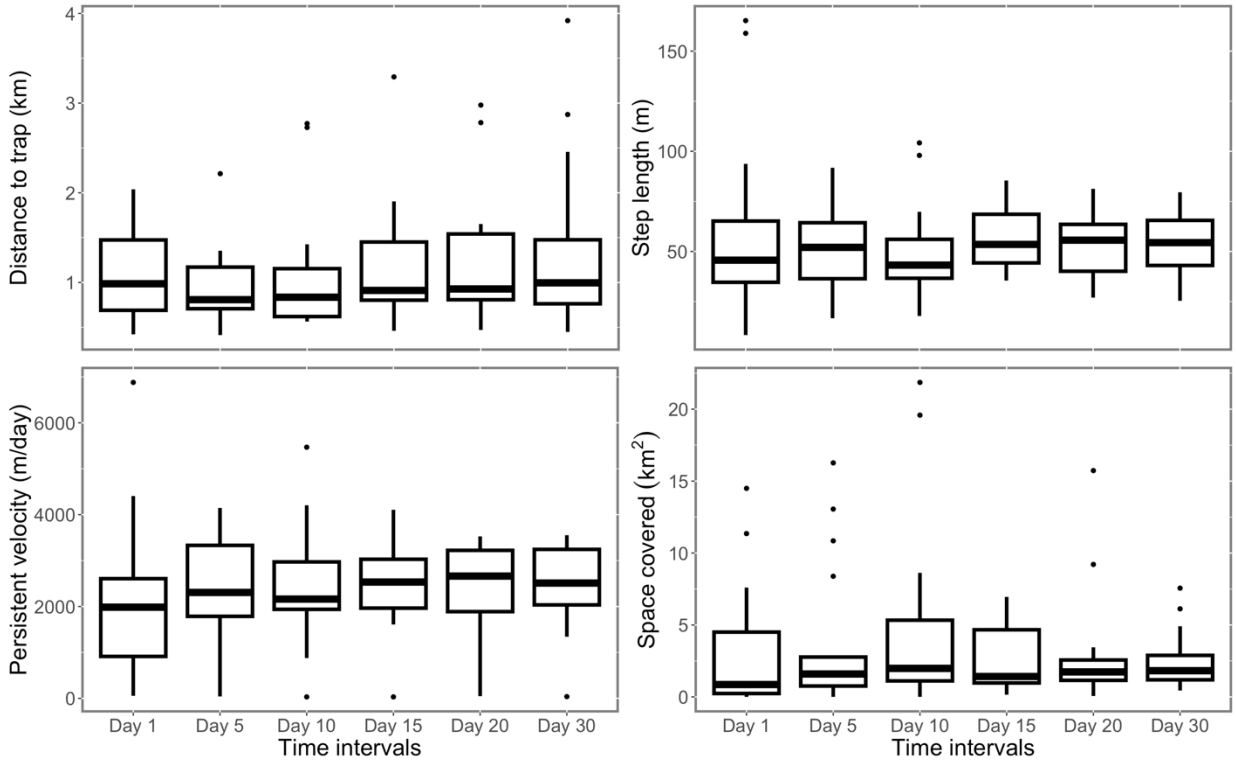


Figure 1.4. Distribution of spatial parameters across six time intervals following sounder removal for GPS-collared wild pigs in the state of Alabama, USA, 2022-2023. Boxplots show values for distance to trap (km), step length (m), persistence velocity (m/day), and space covered (km^2) at days 1, 5, 10, 15, 20, and 30 post-trapping. Boxes represent interquartile ranges (IQR), with medians as bold lines; whiskers extend to 1.5 x IQR, and dots represent outliers.



Chapter 2: Return or Roam? Movement behaviors of wild pigs following a trapping event.

Abstract

Understanding how invasive wild pigs (Sus scrofa) respond behaviorally to social disruption is critical for improving control strategies and preparing efficiently for disease emergencies. We monitored 18 GPS-collared wild pigs across multiple sites in Alabama following trapping-induced isolations. We classified daily movement segments into six behavioral movement patterns—encamped, round and semi-round trip, ranging, wandering, and exploring—using a net square displacement modeling framework. We modeled the proportion of time allocated to each movement pattern as a function of time post-trapping and sounder social composition using multinomial mixed-effects regression. Our findings revealed that wild pigs exhibited a marked decline from unstructured roaming movement patterns (wandering and exploring) in favor of structured, site-fidelity patterns (encamped and round-trip) following isolation. The odds of round-trip behavior increased by 2.8% per day among pigs from sounders with a greater percentage of adults, suggesting an increasing reliance on spatial routines and site fidelity. Additionally, adult-rich sounders were associated with a 2.6% increase in encamped behavior early in the post-trapping period, though this effect diminished over time as pigs gradually transition towards semi-roundtrip, wandering, and exploring behaviors. These patterns reveal that post-disturbance movement strategies are not only time-dependent but shaped by the original social structure, with implications for understanding behavioral flexibility in response to isolation. Rather than dispersing broadly, isolated individuals generally showed movement patterns that kept them within familiar areas. Integrating spatial behavioral ecology into invasive species control efforts offers a powerful framework for anticipating animal responses to disturbance and increasing the effectiveness of management actions under real-world challenges.

Introduction

Animal behavior is shaped by a dynamic interplay of environmental stimuli, physiological needs, and, perhaps most crucially, the intricate social system animals navigate (Doherty et al., 2021; Seebacher & Krause, 2017). For social species, disruptions of social structures can profoundly influence behavioral responses, affecting not only resource acquisition

strategies (Vanak et al., 2013) or survival outcomes (Busson et al., 2019), but decision-making (Shannon et al., 2013) and movement patterns (Doherty et al., 2021). For example, in laboratory experiments, socially isolated Common degus (*Octodon degus*) exhibited increased anxiety-like behaviors and declined in working memory (Cavieres et al., 2023). In wild populations, social fragmentation may result from anthropogenic pressures. In European badgers (*Meles meles*), culling operations have been shown to elevate stress levels, weaken immune responses, and promote intergroup movements, ultimately contributing to greater exposure to pathogens (Riordan et al., 2011). These examples highlight the critical importance of understanding how social disturbances impact animal behavior, as such disruptions can influence broader ecological dynamics and the resilience of species.

One species exemplifying the complexity of social behavior is the wild pig (*Sus scrofa*), a highly adaptable and invasive species with notable negative effects on biodiversity and crop production worldwide (Bengsen et al., 2014; McDonough et al., 2022; Strickland et al., 2019). Wild pigs form structured social groups (sounders) composed of related females and their offspring (Titus et al., 2022), generally exhibiting strong site fidelity where they travel in cohesive associations (Iacolina et al., 2009; Titus et al., 2022). These social bonds are fundamental to many aspects of their ecology, including resource acquisition (Kilgo et al., 2021), anti-predator responses (Bastille-Rousseau et al., 2021), and spatial behaviors (Evans et al., 2024). Disrupting these social structures has the potential to affect movement patterns and behaviors, and thus overall fitness of wild pigs (Clontz et al., 2023).

Because wild pigs are an invasive exotic across much of the globe, considerable efforts are expended controlling or reducing populations. Trapping is one of the most effective and widely used population control methods for wild pigs (Ditchkoff & Bodenchuk, 2019; Kilgo et al., 2023). Management efforts often emphasize whole-sounder captures to prevent recolonization and minimize the likelihood of adaptive behavioral responses that hinder future trapping (Garabedian & Kilgo, 2024; Keuling & Massei, 2021; Kilgo et al., 2023; Lewis et al., 2022). However, captures of entire sounders can be logistically challenging, and often, trapping efforts result in captures of partial sounders where one or more individuals are remaining after the trapping event and they become socially isolated. Such isolations have the potential to

trigger changes in movement behavior as individuals adapt to the sudden loss of social cohesion (Clontz et al., 2023). These behavioral shifts not only affect survivability and resource-selection, but can also influence broader ecological processes such as habitat use and behavioral association with other wild pigs (Genov et al., 2017; Krull et al., 2013; Massei & Genov, 2004). In the context of control efforts, such isolations have the potential to alter the ability to successfully eradicate local populations and possibly spread disease if isolation results in dispersal behaviors (Downing et al., 2023; Yang et al., 2021).

Despite the ecological and management significance of these behavioral responses to social disruption, limited research has explored how wild pigs allocate time to different movement behaviors following such disturbances. This study aims to address that gap by investigating the temporal progression of movement behaviors in lone wild pigs following trapping-induced isolation, with particular emphasis on the time allocated to each distinct behavioral movement. Our specific objectives were to (1) describe the time allocated to each behavioral movement following isolation from a trapping event and assess changes in their relative prevalence, (2) evaluate how social structure and composition prior to isolation influenced the proportion of time spent in each behavior, and (3) identify temporal inflection points in behavioral trajectories to better understand shifts in movement behaviors use over time.

Methods

Study areas

The study was conducted across various properties in five southeastern Alabama counties located in Alabama's Coastal Plain Region.: Bullock, Dale, Geneva, Henry, and Russell Counties. These sites were chosen due to their participation in the USDA's Federal Swine Eradication and Control Pilot Program (USDA, 2018) and/or collaborations with USDA APHIS Wildlife Services. Topographically, the elevation across the study sites ranged from 104-201 m, and study areas were comprised of a diverse mix of ecosystems including agricultural fields, forested lands, and wetlands. The dominant vegetation consisted of various pine species (*Pinus taeda, P. elliottii, P. palustrus,* and *P. echinata*), interspersed with patches of mixed hardwoods

(*Quercus alba, Q. rubra, Carya* spp.*, Liquidambar styraciflua, and Liriodendron tulipifera*). The region experiences a humid subtropical climate, with an annual mean temperature of 19.2 °C; seasonal fluctuations range from winter lows of 11.7 °C to summer highs of 26.2 °C (NOAA, 2024).

Wild Pig Trapping and Monitoring

Between February 2022 and March 2023, we conducted opportunistic trapping of wild pig sounders using corral traps baited with whole kernel corn. To identify active sounder locations, we performed remote camera surveys (Gomez-Maldonado et al., 2024; Williams et al., 2011). Upon locating a sounder, we constructed traps on-site. Each corral trap consisted of five 4.9-meter panels arranged in a circular formation, with a 0.5-meter overlap between panels to enhance structural stability. Panels were secured with 1.6-meter T-posts and bailing wire. A 2.4-meter M.I.N.E.™ Gate (Jager Pro, Fortson, GA, USA) served as the trap entrance and was remotely operated. Trap sites were monitored nightly from 1700 to 0600 using M.I.N.E.™ Cams to observe pig activity and control the gate. The trap remined open for several nights to allow pig to acclimate. Once the entire sounder consistently entered the trap, we remotely triggered the gate to capture the sounder.

Upon capturing a targeted sounder, we randomly selected one adult female (~40 kg) from each group to be fitted with a GPS collar. Adult females were chosen due to their importance in population management strategies (USDA APHIS, 2015). To facilitate the collaring process, we constructed an additional section within the trap to isolate the selected individual from the rest of the sounder. The pig was restrained with ropes and was blindfolded to minimize stress. We then secured a Telonics® GPS/Iridium collar (model TGW-4470-4, Telonics Inc.) around the neck area. Collars were programmed to record location data every 15 minutes for a 180-day period, after which they were automatically released and retrieved. After collaring of the selected individual, we euthanized all remaining members of the sounder, and then released the collared wild pig. We recorded detailed information on sounder composition, including the number of adults and juveniles, and the sex of each individual. We classified pigs estimated to weigh more than 25-30 kg as adults.

Ethical Considerations

We coordinated our trapping and handling procedures with USDA APHIS Wildlife Services personnel, who advised landowners and hunters to avoid targeting collared pigs. However, landowners retained the discretion to manage wild pigs as part of their usual practices. None of the study sites had been previously included in Wildlife Services' trapping efforts, although wild pig populations in these areas were occasionally subjected to hunting and control methods. All animal handling in the study was approved Auburn University's IACUC with protocol number (PRN 2022-4026).

Statistical analysis

We conducted a multi-step process for the statistical analysis of the animal movement data following a modified version of the framework proposed by Morelle et al. (2017). The analytical process comprised: (1) segmenting movement data into discrete phases using Behavioral Change Points Analysis (BCPA) (Gurarie, 2013), (2) characterizing candidate movement behaviors and expressing them through linear or nonlinear models that describe a relationship between net squared displacement (NSD) and time after release, and (3) fitting these models to the NSD segments and identifying the most appropriate movement behaviors based on Concordance Criteria (Huang et al., 2009; Morelle et al., 2017), Akaike's Information Criterion (Akaike, 2011), and other detailed segment-specific metrics. This approach allowed for detailed segmentation of fine-scale movement behaviors and the evaluation of behavioral changes after a trapping event. All analyses were conducted using R version 4.3.1 (R Core Team, 2023).

We began by curating the data, removing erroneous locations (*i.e.,* GPS signal loss or positional drift), duplicates, and missing observations. We defined the date and time of the final recorded location for each individual as either the point where the collar emitted a mortality signal—indicating the animal was deceased—or the time of collar detachment if the animal remained alive. We then subset the GPS tracking data to focus only on the first month (30 days) following the trapping event, as this timeframe aligns with typical management practices (Ditchkoff & Bodenchuk, 2019).

STEP 1: Segmenting movement tracks

We segmented the 30-day movement of each wild pig using BCPA with the bcpa package in R (Gurarie, 2013). This method allowed us to detect changes by partitioning movement data into discrete track segments, each representing a potentially distinct movement pattern. Following recommendations of Morelle et al. (2017), we standardized BCPA parameters across all individuals to ensure consistency in segmentation outcomes. We defined a window size of 12 hours (48 GPS points), a sensitivity parameter *K* of 3, and a cluster width of 4 hours (16 points) for the BPCA. The window size represents the duration of movement data (in hours) that was analyzed at a time to detect changes in behavior—here, each 12-hour block of 48 points was assessed for potential breaks. The sensitivity parameter K controls how easily the algorithm detects shifts in behavior; lower values make it more sensitive, while greater values reduce the number of breakpoints detected. The cluster width refers to the size of smaller groups of GPS points that the algorithm compares within each window to identify potential change points. This helps the algorithm pinpoint where movement patterns begin to shift within the larger window. Each segmented track was assigned a unique identifier (*e.g.,* trip 1, trip 2, …, trip *n*).

STEP 2: Classifying segments into movement behaviors

We used a modified version of the movement mode classification framework developed by Morelle et al. (2017), which objectively assigns GPS tracks segments into distinct movement behaviors using model-fitting approaches based on net squared displacement (NSD). We calculated NSD using the amt package (Signer et al., 2019), which measures the squared linear distance between the starting location and the position at a given time *t*. The movement patterns themselves (encamped, round/partially round trips, wandering, ranging, and exploring) were defined a priori based on published descriptions of wild pig spatial behavior (*e.g.,* Bunnefeld, Börger, Van Moorter, et al., 2011; Keuling et al., 2010; Markov et al., 2004; Prévot & Licoppe, 2013; Scillitani et al., 2010; Spitz & Janeau, 1990; Suselbeek et al., 2014), and represent ecologically meaningful patterns rather than statistical artifacts (Table 2.1 and Figure 2.1).

We classified each movement segment into one of six predefined movement behaviors by fitting five distinct models relating time to NSD and comparing model fit. Each model was designed to capture the NSD signature of a specific behavior pattern; thus, the best-fitting model was used to infer the behavior the pig most likely exhibited during that segment. For each segment, we assessed the fit of linear and nonlinear curve equations representing movement behaviors to the NSD data. We used the FlexParamCurve package in R (Oswald et al., 2012), which supports up to 32 simplified versions of the 8-parameter double Richards curve (for more details see Morelle et al., 2017), enabling us to model a broad range of time-NSD relationships compared to other methods (*e.g.,* Bunnefeld et al., 2011). We used the SSposnegRichards() function to generate starting values for nonlinear least squares models, which we then fit using the nls() function. We also fit linear equations using least square regression for simpler patterns (*e.g.,* encamped or wandering). To evaluate the relative goodness-of-fit for candidate movement patterns for each segment, we used the Concordance Criterion (CC), which offers improved performance over traditional metrics for nonlinear models. Values of CC fall between -1 (perfect negative fit) and +1 (perfect positive fit), representing the agreement between observed data and model prediction. If a model failed to converge, we assigned a CC value of 0. We then selected the best-fitting model for each segment as the one with the greatest CC value.

When the round-trip model produced the best fit, we further distinguished between exploring, round-trip, and semi-round-trip movement behaviors based on the shape of the predicted NSD curve. Specifically, segments were classified as exploring when the final predicted NSD exceeded 1.5 times the model's maximum predicted displacement, indicating sustained outward movement. If the final displacement was closer to earlier values, the segment was classified as either a round-trip or semi-round trip, depending on how fully the return movement was completed. We used the Akaike Information Criterion (AIC) to assess how good the encamped model was relative to the others. If this model had the lowest AIC among all candidate models, we classified the segment as encamped. This fallback approach was used to identify segments with little or no movement structure.

STEP 3: The proportion of time allocated to each movement behavior

To examine how the proportion of time spent on each movement behavior changed over time and in relation to social structure and composition, we created a dataset that quantified the daily allocation of time to each of the six movement behaviors. While we successfully assigned a movement behavior to all track segments for all 18 wild pigs, segment coverage did not always span the entire 24-hour day. To account for missing or unclassified time, we calculated a residual 'other' category to represent unclassified durations, ensuring all daily summaries reflected complete 24 h periods. The high classification success across wild pigs suggests that the behavior classification method was robust in identifying distinct movement behaviors within the dataset. We first compiled a daily summary of all movement segments for the 18 GPS-collared pigs. We then calculated the duration (hours) of each segment and attributed its duration to the day in which the movement occurred. If a segment spanned midnight—beginning on one calendar day and ending on the next—we split the segment into two records: one corresponding to the hours occurring before midnight, and a second corresponding to the remaining hours of the next day. This ensured that all durations were accurately assigned to the correct day and prevented time inflation on either day. After splitting and assigning segments, we aggregated the total duration spent in each movement behavior for each pig on each day.

We used Multinomial Mixed-Effect Regression (MMR) to model how daily time allocation to each movement behavior changed over time and in relation to social composition. This approach allowed us to (1) quantify temporal patterns, (2) assess the influence of social covariates, and (3) identify behavioral inflection points. The response variable consisted of a matrix of daily proportion of time spent in each of the six movement behaviors. Pig ID was included as a random effect to account for repeated measures. We fit all models using the mblogit function from the mclogit package in R (Elff et al., 2022). We first compared temporal models to evaluate whether a quadratic effect of time was supported. Models including a linear effect of day and both linear and quadratic terms were compared to a null model. The model with the quadratic term was selected based on *Q*AIC values (Table 2.2). We then tested whether adding social variables improved the model. Specifically, we evaluated the effects of sounder size, percentage of female (%F) in the original sounder, and percentage of adults (%A), each with and without interactions with time. Values of *Q*AIC indicated that the model including

percentage of adults and its interaction with time and the quadratic term, was the most supported, thus, our final model included day, day^2, %A, %A × day, and %A × day^2 as fixed effects, with pig ID as a random effect. Model selection was based on Quasi-Akaike Information Criterion (QAIC) to correct for potential overdispersion. The overdispersion parameter ($\hat{c}$) was estimated as the model deviance divided by the residual degrees of freedom from a full model (containing all time and social composition variables), and QAIC for each model was calculated as: $\frac{Deviance_i}{\hat{c}} + 2k_i$, where K is the number of estimated parameters.

To aid interpretation of temporal dynamics and calculate behavioral turning points, we further fit six logistic regressions, each isolating a focal movement pattern against all others. For each model, we constructed a binary response matrix with the target movement patterns in one column and the sum of all others as the second column. Each model used the model structure from our final selected model. Turning points—defined as the inflection point in the quadratic trend—were calculated using the formula $\frac{-b}{2a}$, where b and a are the coefficients of day and day^2, respectively.

Results

From 2022-2023, we monitored 18 wild pigs with GPS collars across all study areas, with tracking durations ranging from 7 to 138 days (mean ± SE: 60.61 ± 10.40 days). The number of fixed locations per wild pig ranged from 462 to 84,215 points (4678.61 ± 800.06 points), and daily fixed locations ranged from 25 to 90 points per day (77.33 ± 3.68 points). Sounder sizes of collared wild pigs prior to trapping events ranged from 2 to 18 individuals (8 ± 0.98 pigs) and were comprised of 58.21% ± 6.06 females (range: 0-100%) and 38.34% ± 9.20 adults (range: 0-100%). Across the 30-day period, encamped movement behaviors consistently accounted for the greatest proportions of time spent. (peaking at ~35% around the first week; Table 2.3 and Figure 2.1). Together, with ranging and semi-round trip, these three behaviors made up the majority of observed movement behaviors thought the period, typically comprising over 70% especially after Day 1. Encamped, round trip, and ranging were most prominent in the early days post-trapping (*e.g.,* jointly over 70% by Day 2), while semi-round trip and exploring behaviors increased in

prevalence later—with semi-round trip more than tripling from early to late periods and exploring gradually emerging by Days 15-21.

Effects of Time on Movement Behaviors

Time since the trapping event significantly influenced the time spent on the different movement behaviors (Figure 2.3). The odds of encamped increased by 17.58% with each successive day (Day: ß = 1.62×10^{-1}, SE = 1.757×10^{-2}, $p < 0.001$), though this increase diminished over time by 0.425% per day (Day^2: ß = -4.265×10^{-3}, SE = 4.915×10^{-4}, $p < 0.001$), resulting in an inverted-U curve that peaked around day 19. In contrast, the ranging behavior followed a U-shaped trajectory, with odds decreasing by 7.15% per day (Day: ß = -7.42×10^{-2}, SE = 1.445×10^{-2}, $p < 0.001$) before recovering with a 0.18% increase as days passed (Day^2: ß = 1.852×10^{-3}, SE = 4.636×10^{-4}, $p < 0.001$). Ranging had an inflection point occurring after day 20. We found that wandering declined by 5.97% for each additional day post-trapping (Day: ß = -6.152×10^{-2}, SE = 2.928×10^{-2}, $p = 0.035$) and exhibited a marginally significant quadratic effect ($p = 0.073$) indicating a gradual increase by the end of the 30-day period. Round-trip had the steepest early decline, with odds decreasing by 34.91% for each additional day (Day: ß = -4.295×10^{-1}, SE = 3.875×10^{-2}, $p < 0.001$), followed by a 1.24% increase (Day^2: ß = 1.234×10^{-2}, SE = 1.280×10^{-3}, $p < 0.001$), forming a pronounced U-shaped curved peaking around day 17. Semi-roundtrip and exploring were not significantly influenced by time alone, with neither the linear (Day: $p = 0.616$; $p = 0.753$, respectively) nor the quadratic (Day^2: $p = 0.623$; $p = 0.844$, respectively) terms.

Effects of Social Composition on Movement Behaviors

Based on our QAIC model selection, we found that neither sounder size nor the proportion of females in the sounder prior to the trapping event influenced movement behaviors (Table 2.2). However, the proportion of adults prior to sounder disruption improved the model, indicating that sounder composition shaped post-trapping movement behaviors. Wild pigs from adult-rich sounders were more likely to engage in encamped behavior early on, with odds increasing by 2.56% per unit increase in adult composition (ß = 2.532×10^{-2}; SE = 4.432×10^{-3};

$p < 0.001$). However, this effect declined over time, decreasing by 0.43% per day (ß = -4.313×10^{-3}; 3.17×10^{-5}; $p < 0.001$), though a quadratic interaction (ß = 1.225×10^{-4}; 1.012×10^{-5}; $p < 0.001$) suggested a rebound as time post-trapping progressed (Figure 2.4). We found that as the adult composition in the sounder increased, the odds of round-trip decreased by 2.79% (ß = -2.837×10^{-2}; SE = 8.019×10^{-3}; $p < 0.001$), yet we found that for each additional day, the odds of engaging in this movement behavior increased by 0.52% (ß = 5.197×10^{-3}, SE = 8.306×10^{-4}, $p < 0.001$) for every additional day and we found a negative quadratic effect (ß = -1.532×10^{-4}; SE = 2.815×10^{-5}; $p < 0.001$). Similarly, wandering (ß = -1.729 x 10-2; SE = 8.111 x 10-3; p = 0.033) and semi-round trip (ß = -1.639×10^{-2}; SE = 5.266×10^{-3}; p = 0.001) movement behaviors were initially less likely among wild pigs from adult-rich sounders (-1.71% and -1.62%, respectively); however, both showed a positive effect of day-by-adult composition interactions (ß $_{\text{wandering}}$ = 2.110 x 10-3; SE = 6.525 x 10-4; p = 0.001/ ß $_{\text{semi-round trip}}$ = 1.544×10^{-3}; SE = 3.675×10^{-4}; $p < 0.001$), suggesting that these movement behaviors increased later in the month. We found a quadratic effect on semi-round trip (ß = -5.380×10^{-5}; SE = 1.169×10^{-5}; $p < 0.001$) but not for wandering (p = 0.097). We found that exploring was not directly associated with adult composition (p = 0.507); however, interaction terms revealed an increase over time of 0.26% per day (ß = 2.603×10^{-3}; SE = 7.664×10^{-4}; p = 0.0006), followed by a quadratic decline (ß = -8.168×10^{-5}; SE = 2.378×10^{-5}; p = 0.0005). Ranging showed no main effect of adult composition (p = 0.157), but its odds increased by 0.21% for each day increase (ß = 1.200 x 10-3; SE = 2.811×10^{-4}; $p < 0.001$) with a quadric decline (ß = -3.416×10^{-5}; SE = 9.033×10^{-6}; p = 0.0001).

Discussion

Our results revealed meaningful shifts in how wild pigs allocated time to different movement behaviors following trapping-induced isolation. Wild pigs spent less time engaging in unstructured roaming behaviors—particularly exploring and wandering. Exploring was virtually absent early on, emerging gradually after mid-month, while wandering remained rare until the final week. Both represent dispersive, non-direct movement patterns (Scillitani et al., 2010; Spitz & Janeau, 1990; Waller et al., 2024). In wild boar, wandering has been characterized as non-directional, nomadic movement with steadily increasing displacement from a start point (Miettinen et al., 2023; Scillitani et al., 2010; Spitz & Janeau, 1990), which in this case was the trap site. Exploring, by contrast, entails more purposeful outward movement

without immediate return, often beginning with fast, directed movement followed by slower searching movement (Burke & Whishaw, 2020; Silovský et al., 2024). Both can be seen as exploratory dispersal tactics, analogous to the phase in dispersal theory where animals probe new areas for mates or resources (Bowler & Benton, 2005; Clobert, 2012). Our results indicate that isolated wild pigs reduced these dispersal-like behaviors following isolation, instead favoring more structured movements, such as encamping, round-tripping, and ranging. In other words, even days when pigs were more active, pigs tended to remain near—or attempt to return to—the area where their social group had been disrupted, rather than move persistently away from the area of capture. This trend suggests a behavioral shift toward site fidelity and cautious movement after the disturbance of trapping.

Following the trapping event, wild pigs increasingly relied on structured and spatially conservative movement patterns. Encamped behavior rose sharply within the first week—more than doubling in time allocation compared to the earliest days—and remained consistently high thereafter. Semi-round-trip movements showed a steady, progressive increase in the second and third weeks. In contrast, round-trip behavior was relatively common during the first few days but declined rapidly and was later replaced by more constrained movement behaviors. These three movement behaviors vary in structure and spatial commitment. Round-trip refers to leaving a location and subsequently returning—either completely or partially—to that original location. This pattern is typically associated with foraging loops or patrols of a home range (a "loop" movement sensu; Zadicario et al., 2005). Conversely, encamped behavior is essentially sedentary: remaining within a local vicinity (~200 m) of a focal point with only short excursions (Suselbeek et al., 2014). The increasing prevalence of encamped and semi-round-trip behaviors—together accounting for most of the time allocated by the final week—suggests a stabilization of spatial routines around the area of initial disruption. Similar patterns have been documented from other disturbed wild boar populations: after events like hunts or capture, wild boar initially tended to remain within their established annual home range rather than permanently disperse, indicating strong site fidelity (Keuling et al., 2008). This behavioral conservatism may reflect a form of natal philopatry (Waser & Jones, 1983), the tendency to remain or return to one's familiar terrain. It appears that the disruption of the social group led individuals to opt for familiarity and safety, possibly an adaptive response to uncertain

conditions. By favoring known areas over extended wandering, pigs could exploit familiar resources while reducing risk, potentially waiting for opportunities to rejoin conspecifics. Such wait-and-see strategies have been observed in domestic pigs (Zwicker et al., 2015), suggesting that cognitive flexibility and risk avoidance played a role in shaping these movement trajectories.

Interestingly, the ranging behavior—defined as rapid, directed movement away from a location with no immediate return, analogous to a short-term dispersal event (Keuling et al., 2010; Markov et al., 2004; Prévot & Licoppe, 2013)—remained prevalent throughout the study period (~30%). This is surprising considering the persistent rarity of wandering and exploring behaviors, which remained low or only increased modestly after the third week. In the context of invasive wild pigs, such ranging excursions may serve as an important exploratory function, allowing individuals to locate new resources or vacant areas while retaining the option to settle if conditions are favorable (Froehly et al., 2020; Smith et al., 2023). Morelle et al. (2017) described these movement behaviors as being common in wild pigs that were still associated with their sounder, and our results suggest that even isolated pigs retain this behavior. That said, our data indicate a reorganization of the movement repertoire with time since isolation: pigs showed greater reliance on encamped and round-trip movements compared to earlier periods when exploratory movement patterns were more common, and spent less time in movement behaviors like wandering, which involve unpredictable, wide-ranging movement. Ecologically, this shift might reflect a trade-off between safety and exploration—isolated pigs choose conservative movement to minimize risk (e.g., predation or energy loss) after losing the safety of numbers (Smith et al., 2023).

The social structure of the original group—particularly the proportion of adults—played a key role in shaping post-trapping movement behaviors. Pigs from adult-rich sounders were more likely to exhibit encamped behavior early in the monitoring period. However, this effect diminished over time, and these individuals gradually shifted toward semi-roundtrip, wandering, and exploring behaviors. On the contrary, pigs from sounders with fewer adults tended to adopt less structured movement behaviors earlier, indicating a weaker reliance on spatial routines. This pattern suggests that adult pigs may rely on more robust spatial memory and a stronger internal representation of their home range, which could facilitate site-faithful responses

immediately following social disruption. Individuals from adult-rich sounders may have defaulted to known locations that offered familiarity and safety, possibly reflecting a search strategy rooted in social memory. Although our data cannot confirm whether the movement paths overlapped with pre-trapping home ranges, the tendency to remain in or return to previously used areas aligns with well-documented patterns of site fidelity following disturbance. Wild pigs are known for their cognitive flexibility and strong spatial memory, particularly in cohesive sounders that share foraging routes and refugia (Focardi et al., 2015; Jansen et al., 2009). Similar post-disturbance persistence in familiar areas has been documented in other social mammals, including black-tailed deer (*Odocoileus hemionus columbianus*) after wildfires (Kreling et al., 2021), elk (*Cervus canadensis*) and caribou (*Rangifer tarandus*) following human disturbance (Gerber et al., 2019; Merkle et al., 2022), and primates in fragmented forests (Mitani & Watts, 2005). These patterns suggest that social experience and memory may buffer individuals against abrupt environmental or social change by anchoring their behavior in familiar space. We found no evidence that sounder size or the proportion of females in the original group influenced time allocation of movement patterns following the trapping event. This suggests that it is not the number of groupmates or the dominance of females per se, but rather the maturity of the social unit that most strongly shaped post-trapping responses.

Wild pigs did not adjust their movement behaviors all at once after isolation. Instead, their behavior evolved gradually over the 30-day post-trapping period, following non-linear trajectories shaped by time and social context. Our analyses revealed temporal inflection points across behavioral movements, reflecting a staged process of behavioral adjustment rather than a uniform shift. Initially, pigs reduced their use of encamped behavior, reaching a low point around day 19, while exploring movement patterns like wandering and ranging began to increase—suggesting a transitional phase in which pigs, after a period of spatial caution, began reassessing their environment. Exploring and semi-round-trip behaviors peaked around days 16 to 25, indicating a transient window of outwards probing—perhaps driven by failed attempts to locate conspecifics or to explore new resource areas (Bastille-Rousseau et al., 2021; Saldo et al., 2023; Schlichting et al., 2022; Thurfjell et al., 2013). Previous studies have documented that wild pigs shift their movement patterns in response to factors like predation risk and human disturbance (Thurfjell et al., 2013; Tolon et al., 2009), fluctuating resource availability (Snow &

VerCauteren, 2019), social restructuring (Clontz et al., 2023), and thermal refuge-seeking during hot periods (Franckowiak et al., 2018). These temporal dynamics point to a phased behavioral sequence, in which individuals alternated between caution, exploration, and eventual stabilization. Such time-structured shifts reflect a gradual reorganization of space, consistent with dispersal theory, which describes a progression from exploratory behavior to settlement as individuals adjust to novel conditions (Baguette et al., 2013; Bowler & Benton, 2005; Cayuela et al., 2018; Ferrer, 2015). Importantly, 77% of collared pigs (n = 14) were monitored until the collar release, indicating that observed behavioral engagements reflect sustained responses—not outcomes biased by early mortality or harvest actions to retrieve the collar. However, in our case, pigs were not geographically relocated; instead, the removal of conspecifics may have created a form of social relocation, transforming a familiar landscape into a socially unfamiliar one. Initially, wild pigs may have remained localized, then periodically ventured outward as they assessed the absence of groupmates or attempted to reestablish contact. As these efforts failed or were abandoned, pigs appeared to transition into more sedentary movement behaviors, characterized by increased encamped movement and reduced wandering.

Our results indicate that surviving pigs tended to remain localized rather than dispersing widely following partial group removal. While such behavior may mitigate broadscale disease spread, it could still facilitate local disease transmission. Recent studies have shown that wild pig populations can rebound within months after reduction events due to reproduction by residual individual and immigration into the area (Garabedian & Kilgo, 2024). Additionally, social disruption may elevate physiological stress, which in turn could suppress immune function and increase susceptibility to infection—a pattern observed in other social species such as badgers (*Meles meles*) experiencing culling-induced social breakdown (Riordan et al., 2011). These findings underscore the challenge of managing disease and population growth in invasive species whose behavioral responses to control are both context-dependent and time-sensitive.

Conclusion

Our study demonstrated that trapping-induced isolation prompts wild pigs to shift towards more structured, localized behavioral movement behaviors, particularly encamped and semi-round-trip patterns. Rather than dispersing broadly, most individuals exhibited site fidelity,

with behavioral stabilization peaking around day 19 post-trapping event. These temporal patterns were further shaped by social composition: pigs from adult-rich sounders showed increased initial reliance on localized movement behaviors, likely reflecting stronger spatial memory and prior experience. As time passed, these individuals increasingly incorporated semi-roundtrip and wandering behaviors, suggesting a cautious re-expansion of movement. These results underscore how social maturity may modulate individual behavioral plasticity following social disruption.

From a management perspective, understanding these behavioral dynamics presents both challenges and opportunities. While post-trapping behavioral plasticity allows pigs to adapt, it also creates predictable patterns that managers can exploit. For instance, the tendency for isolated pigs to remain localized for the first two to three weeks suggest that control efforts could be intensified around known activity centers (e.g., former trap sites or known home ranges) during this stabilization window. Additionally, pigs from adult-rich sounders were initially more site-faithful, indicating that ensuring the capture of mature individuals may improve management goals. Conversely, the gradual rise in exploratory behaviors—especially wandering—after day 20 suggests a potential increase in range expansion or contact rates, which may call for early intensive follow-up efforts to prevent reinvasion or local disease transmission. These results highlight that timing, social structure, and behavioral plasticity must all be considered in designing effective, behaviorally informed, control strategies.

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Figures and Tables

Table 2.1. Behavioral movement patterns identified from GPS-tracked data of 18 wild pigs following a trapping event, including movement pattern descriptions, and potential ecological drivers for each behavior.

Behavioral Movement Patterns	Description	Potential Drivers
Encamped	Limited movement, high site fidelity, small spatial extent	Caution, stress recovery, resource-driven residency
Round & Partially Round Trips	Movement away from trap with full or partial return	Risk assessment, social attachment, site fidelity to sounder separation
Wandering	Gradual, linear displacement from trapping site	Uncertain exploratory movement, low-motivation dispersal
Ranging	Fast, directed movement interspersed with slower movement after the trapping event	Flight response, reassessment phases, boundary reestablishment
Exploring	Sustained, outward- directed movement with no apparent return, often reflecting directed exploratory excursions post-trapping	Information-seeking, spatial learning, conspecific search

Table 2.2. Model selection results based on quasi-Akaike Information Criterion (*Q*AIC) for multinomial mixed models predicting wild pig behavioral movement patterns.

Fixed Effects	*K*	Deviance	*Q*AIC [a, b, c]	Δ*Q*AIC [d]
Day + Day^2 + %A + Day*%A + Day^2*%A	45	18206.31	2288.903	0
Full model	75	17760.01	2295	6.097
Day + Day^2	30	18517.11	2296.441	7.538
Day	25	18625.82	2299.57	10.667
Day + Day^2 + Sounder size + Day*Sounder size + Day^2*Sounder size	45	18311.57	2301.616	12.713
Intercept only	20	18736.21	2302.903	14
Day + Day^2 + %F + Day*%F + Day^2*%F	45	18333.67	2304.285	15.382
Day + Day^2 + %A	35	18506.01	2305.1	16.197
Day + Day^2 + %F	35	18509.34	2305.502	16.599

[a] *Q*AIC was computed using a quasi-likelihood correction with estimated overdispersion ($\hat{c}$ = 8.279), derived from the full model.

[b] *Q*AIC was calculated as: $\frac{Deviance}{\hat{c}} + 2k$, where *K* is the number of estimated parameters, and $\hat{c}$ is the overdispersion parameter.

[c] Lower *Q*AIC values indicate better model fit.

[d] Δ*Q*AIC represents the difference from the top-ranked model.

Table 2.3. Proportional time allocation (%) to behavioral movement patterns across six time periods following the trapping event for GPS-collared wild pigs (n=18). Values represent the percentage of all classified movement segments assigned to each behavioral movement pattern within each period. The percentage may not sum to 100% due to rounding.

Period [a]	Encamped	Round trip	Semi-round trip	Wandering	Ranging	Exploring	Other
Day 1	15.50 %	9.70 %	5.19 %	7.74 %	21.70 %	0 %	40.17 %
Day 2	34.40 %	11.80 %	9.53 %	5.50 %	29.30 %	1.90 %	7.52 %
Day 3-7	28.00 %	2.00 %	18.00 %	4.31 %	34.90 %	4.60 %	8.18 %
Day 8-14	26.50 %	3.62 %	25.40 %	4.27 %	32.60 %	3.00 %	5.54 %
Day 15-21	30.40 %	1.36 %	18.60 %	5.22 %	30.50 %	7.25 %	6.73 %
Day 22-30	29.90 %	2.36 %	20.40 %	10.50 %	28.00 %	3.47 %	5.42 %

[a] Time periods were used for interpretive summaries only and were not included in formal statistical models. Percentages may not sum to 100% due to rounding.

Figure 2.1. Visual representations of six distinct movement behaviors exhibited by GPS-tracked data of wild pigs. Each trajectory represents a simplified pattern of movement. Trap locations points are indicated in green, ending points in red, and intermediate points in black. Different line types distinguish the movement trajectories for each behavior.

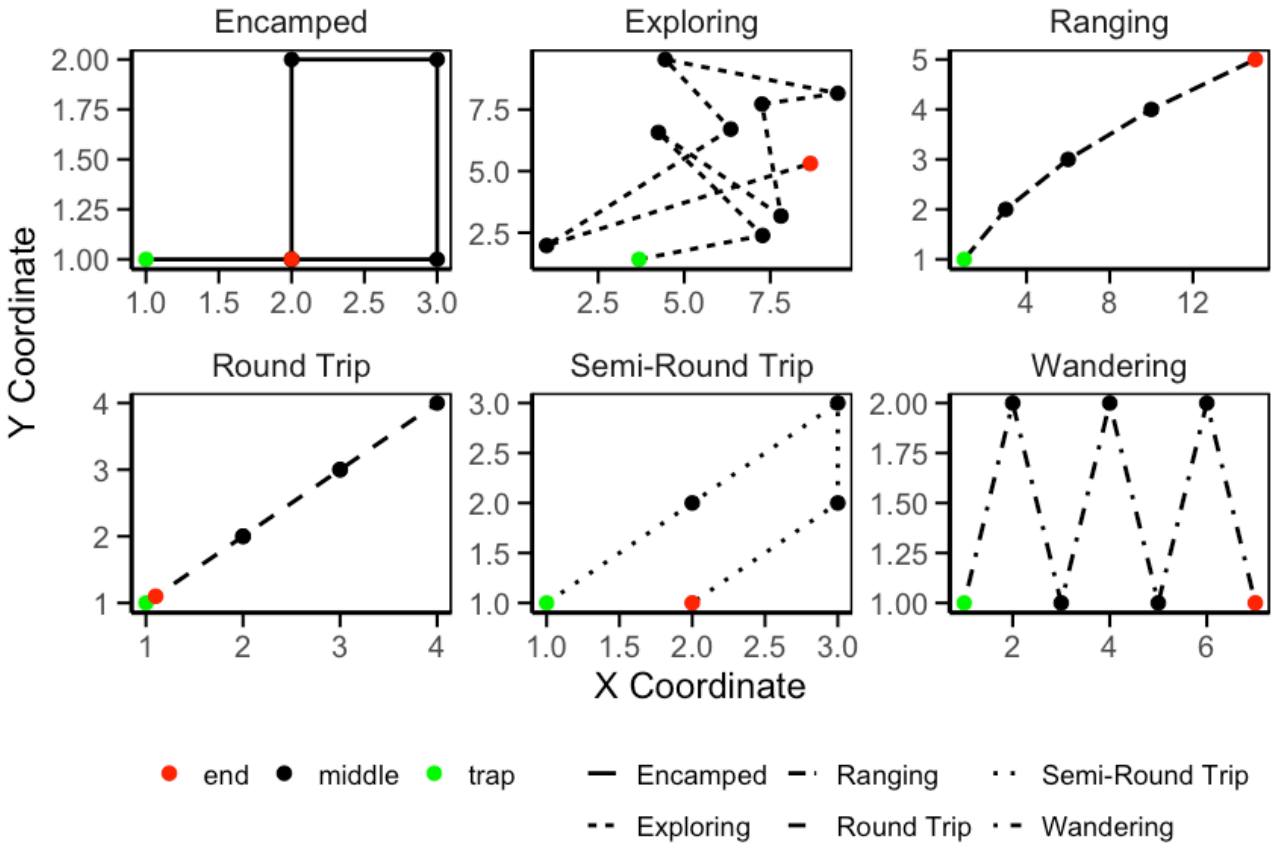

Figure 2.2. Daily proportion of time allocated to each behavioral movement pattern by GPS-collared wild pigs (n=18) over the first month (30 days) following the trapping event from 2022-2023 in Alabama, USA. Bars represent aggregated proportions of all classified movement segments per day across individuals. Behavioral movement patterns include encamped (residency in limited area), round-trip and semi-round trip (movement away from the trap site with complete or partial returns), wandering (gradual linear displacement), ranging (directed movements interspersed with slower movements), and exploring (sustained outward movements without returns).

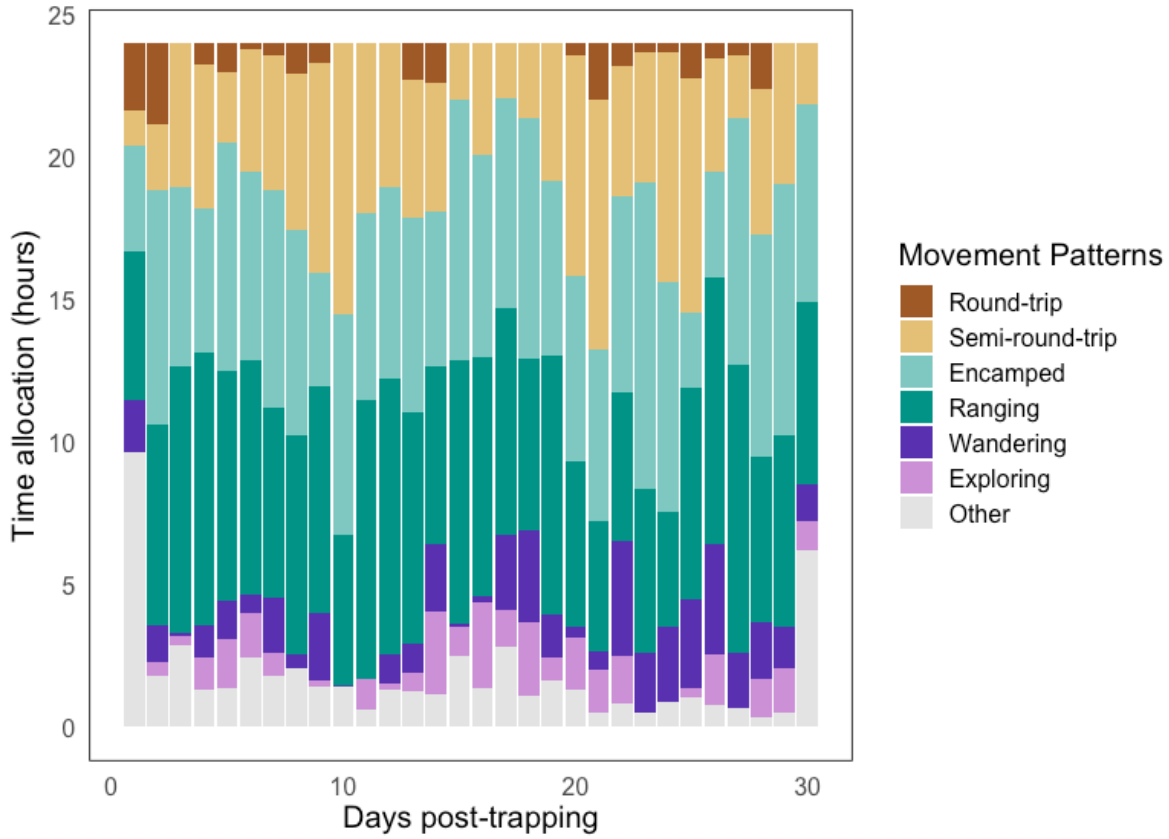

Figure 2.3. Predicted daily proportion of time allocated to each behavioral movement pattern by GPS-collared pigs (n=18) over the first 30 days following the trapping event from 2022-2023 in Alabama, USA. Lines represent model-based estimates of mean behavioral allocation per day. Predictions are based on specific behavior models.

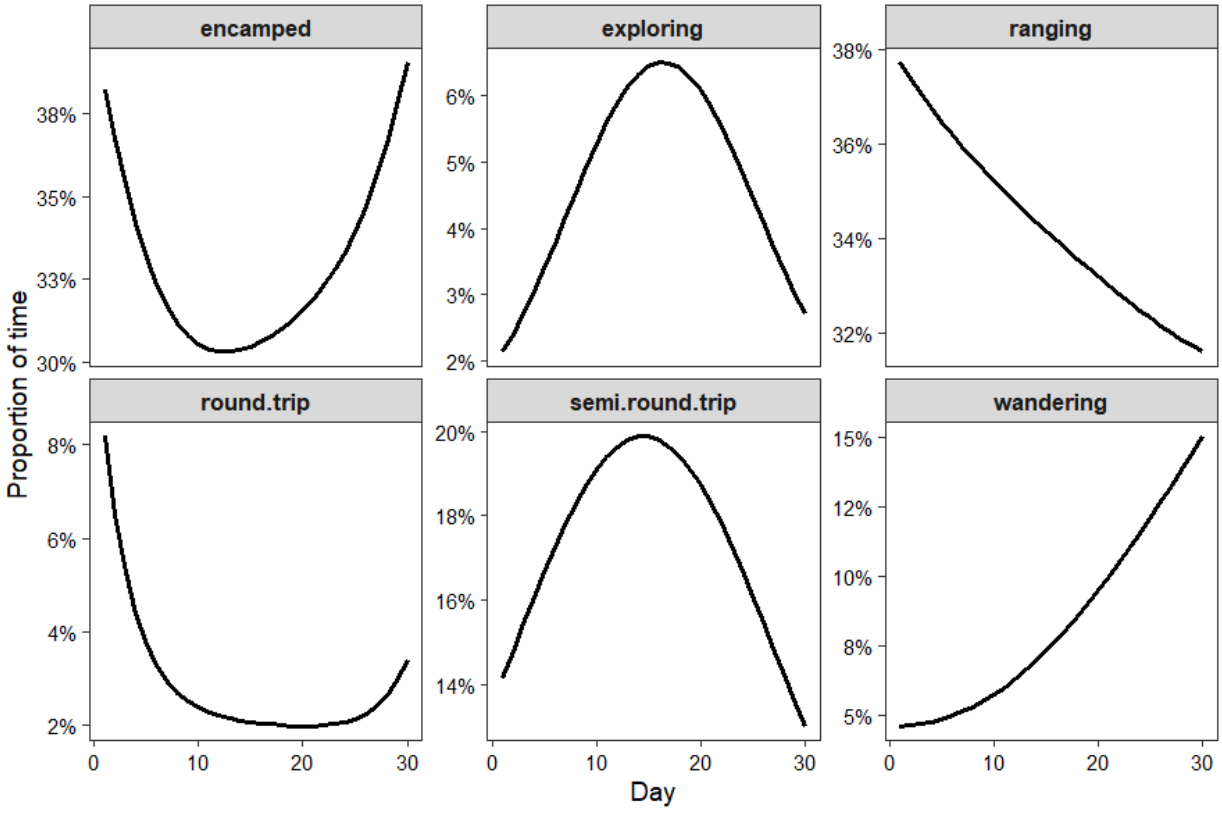
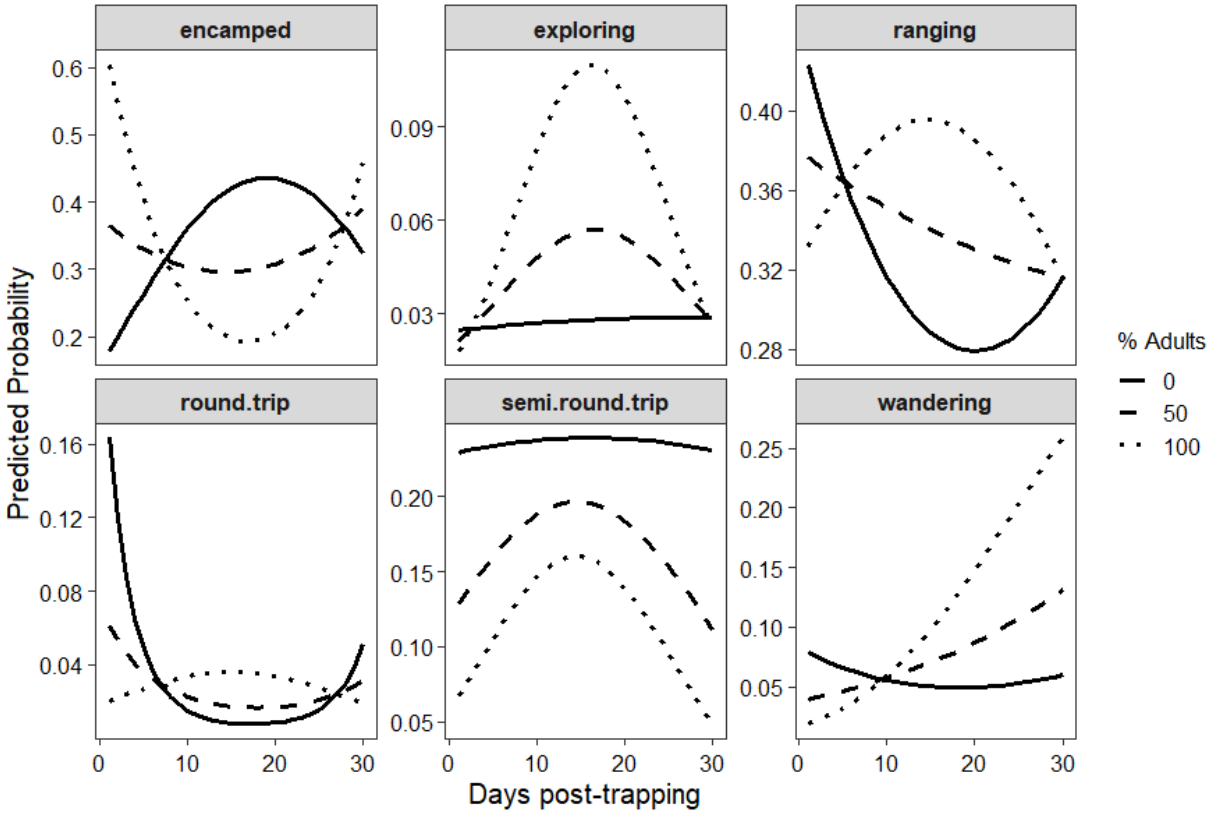
Figure 2.4. Relationship between percentage of adults in the sounder prior to the trapping event and the proportion of time allocated to each behavioral movement pattern for GPS-collared wild pigs (n=18) during the first 30 days post-trapping from 2022-2023 in Alabama, USA.