

The Log Less Travelled:

Investigating the Effect of Time on Route Selection of Woodland Deer Mice,

*Peromyscus maniculatus gracilis*

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## ABSTRACT

For prey animal such as the woodland deer mouse, *Peromyscus maniculatus*, anti-predator behavior is vital to their survival and influences almost every aspect of their life, including route selection. This study evaluated route selection of 16 adult deer mice in two different temporal settings (night and day) to assess different anti-predator strategies. Contradictory to popular literature, the mice were not found to prefer quieter substrate overall, and there was no noted difference in substrate preference (loud leaf litter vs. quiet coarse woody debris) between the two trials. Anti-visual detection behavior was noted in the significant difference of distance traveled between day ( $12.040 \text{ m} \pm 3.576$ ) and night ( $32.375 \text{ m} \pm 7.450$ ), and general behavior notes made during each trial. More intensive behavioral research is necessary to fully understand the influence of anti-visual-predator behavior on the route selection of deer mice.

## INTRODUCTION

Due to the effect of death on an animal's future fitness, anti-predator behavior dictates much of an animal's present behaviors. Active assessment of an animal's risk of predation greatly influences decision making, some in more obvious ways than others (Lima and Dill 1989). A subtler influence of anti-predator behavior can be seen in microhabitat and route selection, wherein the animal avoids detection by predators via dynamic selection of pathways depending on environmental conditions such as illumination (Barnum et al. 1992, Travers et al. 1988, Barry and Francq 1982), substrate type (Roche et al. 1999, Hinkelman et al. 2011), and vegetation cover (Travers et al. 1988, Hinkelman et al. 2011, Barnum et al. 1992).

The choice of quieter substrate types in order to decrease auditory detection by predators is a well-known strategy of animals, and has been well studied with the deer mouse *Peromyscus maniculatus*. Roche et al. (1999) determined that deer mice prefer to travel on fallen logs and other coarse woody debris (CWD) rather than louder leaf litter, and within leaf litter itself prefer the quieter coniferous needles. Due to the amount of deer mice predators that use auditory cues to hunt, including but not limited to owls (Strigidae), minks (*Neovison vison*), martens (*Martes americana*), least weasels (*Mustela nivalis*), bobcats (*Lynx rufus*), coyote (*Canis latrans*), and foxes (*Urocyon cinereoargenteus* and *Vulpes vulpes*) (Sullivan 1995), it is understandable that anti-predator behavior is expressed in preference for quieter pathways.

However, auditory detection is not the only strategy of deer mice predators. Many predators of deer mice have and use multiple hunting strategies, including visual and olfactory, and thus auditory anti-predator behavior is likely not the only strategy when avoiding predators. For olfactory predators, little can be done in terms of avoidance aside from aggregation (Johannesen et al. 2014, Cramer pers. com.), but anti-visual predator behavior is already well documented within *Peromyscus spp.* and *Peromyscus maniculatus* in the form of vegetation cover and illumination preference (Travers et al. 1988). As a nocturnal animal, deer mice already actively avoid visual predators by restricting their activities to the nighttime, and have been shown to further decrease their activity on more illuminated nights (Barry and Francq 1982). Additionally, on brighter nights the use of vegetation cover by deer mice also increases, showing further visual predator avoidance. This goes not without cause; the predation and successful capture of deer mice by short-eared owls (*Asio flammeus*) increases on more illuminated nights (Clarke 1983). Although the visual acuity of deer mice is more heightened than that of most

rodents (King and Vestal 1974), and thus the additional moonlight can be used to their own advantage, the minimization of predation risk wins out as the determining behavioral factor.

In order to further investigate how the predator avoidance strategies affect the route selection of deer mice, the pathways of released woodland deer mice, *Peromyscus maniculatus gracilis*, were assessed in terms of length, direction, general coverage, general illumination level, and substrate. Two hypotheses were tested: 1. there should be a preference for herbaceous coverage in the day trial mice when compared to night trial, and 2. night mice should have a preference for quieter substrates when compared to day mice.

## MATERIALS AND METHODS

### Study Sites

*Peromyscus maniculatus* is found throughout the forests and fields of the University of Notre Dame Environmental Research Center (UNDERC), located on the border of the Upper Peninsula of Michigan and northern Wisconsin (46° 13' N, 89° 32' W). UNDERC is an area of about 6153 acres with 30 lakes and bogs with a combined area of 1347 acres and mostly northern mesic forests (Curtis 1959). The sites for trapping and release consisted of mixed hardwood forests (*Acer saccharum*, *Acer rubrum*, *Abies balsamea*, *Picea glauca*, *Betula alleghaniensis*, *Tsuga canadensis*), with little to no understory growth. Six sites were chosen for this specific forest composition and predicted high *Peromyscus spp.* density (Figure 1).

### Trapping Protocol

*P. maniculatus* individuals were caught via live-trapping in July 2019. Trapping grids contained 25 traps in a 5 x 5 configuration with 15 m spacing, or a half grid containing 15 traps in a 3 x 5 configuration, 15 m spacing. All mice were live-trapped using Sherman traps (7.62 x

8.99 x 22.86 cm; H. B. Sherman Traps, Inc., Tallahassee, FL) baited with sunflower seeds. When captured, mice will be identified as *P. maniculatus* using ear length (Lindquist et al.2003; Ridenhour and Cramer 2015), and then sexed, weighed, and marked with ear tags (monel 1; National Band and Tag Co., Newport, KY).

### **Field Site Description**

The grids and half grids were sectioned into quadrants (*Figure 2*). The center point of each of quadrant was used as a common release point for any mouse caught within said quadrant. For the mice on the gridlines between two or more quadrants, the quadrant of their release was determined randomly.

### **Experimental Procedure**

Following capture all adult mice, excluding lactating and pregnant females, were taken to the laboratory and housed in individual cages (19 x 29 x 12.5 cm) for a minimum of 24 hours and a maximum 40 hours. The captured adult mice were given a mix of paper fiber and corn grains for bedding, polyfill nesting material, and water and food (rat pellets, sunflower seeds) *ad libitum*.

For the trials, mice were randomly selected to be released during the day between 1100 and 1400 or at night from 2100 to 2300. The mice were transferred into Sherman traps and transported back into the field, where they were again transferred to a “rainstick”. The rainsticks are approximately 30 cm long 1 ¼” polyvinyl chloride (PVC) pipe with capped ends. The three rainsticks each contained approximately a teaspoon of BioQuip Luminous Powder (BioQuip Products, Inc., Rancho Dominguez, CA) in either yellow, red, or blue. Different rainsticks were used for each powder to avoid cross-contamination of colour, and different colours were used for multiple releases within the same area. Once the mouse was inside the capped rainstick, the

rainstick was slowly inverted multiple times in a span of 30 s to 1 minute to ensure total coverage of the mouse by the powder.

After powdering, the mouse was released near the quadrant's center flag in an arbitrary direction. Upon release, myself or my assistant would videotape the mouse using an iPhone XR (Apple Inc., Cupertino, CA) within the best of our ability without following the mouse closely, to avoid further distressing the mouse or affecting the mouse's path. A timer was set upon release as well, and after 10 minutes data collection would begin.

Data collection begun by following the mouse's trail of fluorescent powder using a portable ultraviolet flashlight (Glossday). Stake flags were placed at turns and substrate changes in the path. The path was followed to the point the mouse was known to have taken until the 10-minute mark, or to the greatest extent possible given the visibility of the powder. Following the day trials, distance, direction, canopy density, herbaceous layer coverage (existence of plant coverage shorter than 50 cm), and substrate type was recorded. The night trial data were recorded the following day for simplicity.

### **Statistical Analysis**

Proportion of total distance traveled on leaf litter (hardwood forest leaves) versus CWD (logs, tree roots, stumps, bark), total distance, total number of path deviations, and proportion of path distance spent exposed (not under herbaceous coverage) was analyzed for each trial type (night and day). All statistical analyses were conducted with R Studio Version 1.1.463 (R Development Core Team 2008). All animal use complied with the American Society of Mammalogists guidelines (Sikes et al. 2011). All statistics are reported as means  $\pm$  standard error of the means.

## RESULTS

A total of 16 adult mice (12 male, 4 female *Peromyscus maniculatus gracilis*) were evaluated for route selection. More males were used in trials due to the presence of pregnant or lactating females. Total distance was not normally distributed (Shapiro-Wilk test:  $W = 0.864$ ,  $P = 0.022$ ), nor was the variance homogenous ( $\chi^2 = 84.738$ ,  $df = 1$ ,  $P = 0.000$ ), so a Kruskal-Wallis test rather than a one-way ANOVA was done and revealed night trial mice paths ( $32.375 \text{ m} \pm 7.450$ ) were significantly longer than day trial mice paths ( $12.040 \text{ m} \pm 3.576$ ;  $\chi^2 = 4.4118$ ,  $df = 1$ ,  $P = 0.036$ ). The deviation count between night and day trials was also not normally distributed (Shapiro-Wilk test:  $W = 0.878$ ,  $P = 0.036$ ), nor was the variance homogeneous ( $\chi^2 = 77.968$ ,  $df = 1$ ,  $P = 0.000$ ), but the night mice deviation count ( $34.000 \pm 5.435$ ) was found to be significantly different from day mice deviation count ( $15.750 \pm 2.827$ ;  $\chi^2 = 6.372$ ,  $df = 1$ ,  $P = 0.0116$ ) using a Kruskal-Wallis test. A proportion of total distance spent outside of cover, referred to as distance exposed, was not normally distributed as well (Shapiro-Wilk test:  $W = 0.871$ ,  $P = 0.029$ ) nor had homogeneous variance ( $\chi^2 = 13.254$ ,  $df = 1$ ,  $P = 0.000$ ), but was not significantly different between night ( $0.749 \pm 0.075$ ) and day trials ( $0.743 \pm 0.116$ ;  $\chi^2 = 1.337$ ,  $df = 1$ ,  $P = 0.248$ ).

The proportion data of distance spent on different substrate type (leaf litter or CWD) were normally distributed (Shapiro-Wilk test:  $W = 0.897$ ,  $P = 0.073$ ). The data were then evaluated using a one-way ANOVA, with no significant difference found between the night ( $0.232 \pm 0.082$ ) and day proportions of time spent on CWD compared to leaf litter ( $0.279 \pm 0.070$ ;  $F_{1, 14} = 0.189$ ,  $P = 0.670$ ).

## DISCUSSION

Although a strong preference for a substrate type was shown in both day and night trials, the stronger preference for leaf litter as compared to coarse woody debris (CWD) was unprecedented and nonsignificant between the trials. This contradicts the first hypothesis predicting a stronger CWD preference in the night trials than the day trials, and previous studies done that displayed a preference for CWD compared to the noisier leaf litter (Roche et al. 1999). It also is contradictory to multiple other studies done which have shown deer mice prefer the quieter substrate of CWD than leaf litter (Roche et al. 1999, Fitzgerald and Wolff 1988, Barnum et al. 1992), as the rustling of leaves produce sounds (8 kHz; Payne 1971) well within the audial range of many small mammal predators (Roche et al. 1999).

In terms of the day and night trials, the lack of significant preference for CWD between the two indicate that mice consistently display anti-auditory-predator behavior regardless of the time. Constant avoidance of auditory detection is likely from the ever-present danger of auditory predators. The initial first hypothesis, that night trial mice would preferentially travel on CWD, considered owls as the predominant auditory predators, and as majority owls are nocturnal, night trial mice would prefer the quieter substrate more than day mice. However, mostly all diurnal and nocturnal predators tend to hunt using auditory cues, and one of the owl species occurring at UNDERC, the barred owl (*Strix varia*), hunts both nocturnally and diurnally (Kaufman 2019).

A similarly surprising result was found by in a study by Hinkelman et al. (2011) involving decreased foraging around and on CWD. Much like my own study and Roche et al. (1999), Hinkelman et al. (2011) expected CWD to be used more often than leaf litter in foraging behavior. After discovering that this was not the case, it was concluded the lack of CWD preference was most likely due to the use of the logs by snakes (primarily Viperidae) as ambush sites (Reinert et al. 1984). However, in the northern hardwood forest where this study took place,

only snakes of the Colubridae family are found, and none are classified as potential predators for deer mice (Sullivan 1995). Thus, decreased use of CWD due to potential threats is an unlikely conclusion for this unexpected preference.

Another possible explanation for the preference towards leaf litter could come from the moisture conditions of the leaf litter, as dampened leaf litter is known to be significantly quieter than dry leaf litter and actively increase deer mice substrate preference (Roche et al. 1999). General moisture conditions were recorded for each trial (wet or dry), and no more than 1.27 cm of precipitation was recorded for the days wherein trials were completed. No trials were completed during the rain. Of the 16 trials, 8 were completed in dry conditions and 8 in wet. Five of the wet conditions were night trials, 3 day; three of the dry conditions were night trials, 5 day. The proportions of distance spent on leaf litter and CWD were evaluated for normality using a Shapiro Wilk test ( $W = 0.897$ ,  $P = 0.072$ ), and preference between condition type (wet vs. dry) using a one-way ANOVA. There was no significant difference in proportion of distance spent on CWD compared to leaf litter between the wet trials ( $0.299 \pm 0.066$ ) and dry trials ( $0.212 \pm 0.079$ ;  $F_{1, 14} = 0.696$ ,  $P = 0.418$ ). This lack of preference between dry and wet leaf litter further contradicts the experimental results of Roche et al. (1999), as it depicts no evident behavior in avoiding auditory detection playing into route selection.

The lack of significant difference in cover preference between day and night trials could stem from a similar explanation as the lack of substrate preference between day and night as well – regardless of time, deer mice exhibit similar anti-predator behavior. This is likely caused by the plethora of predators of deer mice (Sullivan 1995) and the multiple different hunting strategies used. An abiotic factor unaccounted for in the study could also be the cause of this lack of preference, the moon's illumination. For the week of trial releases (July 12<sup>th</sup> to July 17<sup>th</sup>, 2019),

the moon transitioned from waxing gibbous to waning gibbous (Calendar n.d.) and was at peak illumination. A study done by Jacob et al. (2017) showed that foraging decreased in exposed forest areas (lacking vegetation cover) during times of increased illumination in *Peromyscus spp.* Thus, this constant high level of illumination present during the night trials may have increased herbaceous cover use, skewing the results in an unanticipated way. Further studies investigating moonlight effects on *Peromyscus maniculatus* vegetation cover use is necessary to understand these results.

Additionally, deer mice are nocturnal, and thus they lack specific diurnal behavior due to their natural lack of activity at that time. However, there was an informal observation made by myself and fellow researchers that was specific to the day trials. The mice would often pause and remain still for moments at a time until moving again, a behavior that was entirely unseen during the night trials. This behavior, known as intermittent locomotion, characterizes prey animals and helps avoid detection by predators (Kramer and McLaughlin 2001). Thus, although cover preference did not significantly change between the trials, there was still evidence for anti-visual-predator behavior during the day trials. More intensive studies regarding diurnal deer mouse behavior is necessary to evaluate their use of intermittent locomotion, and how it could affect their route selection.

The significant difference in total path distance between the day and night trials are the best evidence for anti-predator behavior strategies in deer mice (*Figure 3*). Excluding one day trial, all day mice returned to a place of safety (tree stump, hollow tree, branch pile) that was nearby and relatively close to the ground, whereas many of the night trial mice (4; trials 8, 11, 13, 17) had no end location at a place of safety, and traveled so far that the fluorescent trail was unable to be accurately tracked. Additionally, no day mice climbed a tree higher than the 1 m

mark, while 3 of the night mice (trials 5, 10, 16) climbed and remained in trees. The shorter distance traveled, lack of climbing observed, and informal observations of intermittent locomotion, are strong evidence for anti-visual-predator behavior in mice route selection, but further behavioral research is needed.

The limitations of this study are evident in the low sample size and lack of constant environment. Because familiarity is shown to effect small mammal route selection (Clarke et al. 1993, Stamps 1995), the mice were released in the same grid quadrant as they were caught. This caused changes in environment that may have accounted for substrate choice and vegetation cover. Further studies should be done in more similar areas or the same area. Additionally, the prevalence of lactating and pregnant females in the research area caused for a biased for male mice. Future studies ought to investigate the possible difference between male and female deer mice locomotion and route selection, as it was not possible in this study.

However, this study shows important contradictions in previously accepted anti-predator behavior of deer mice. The lack of preference for coarse woody debris compared to hardwood leaf litter across is reason to believe deer mice actively make no behavioral changes to avoid auditory detection, and more field research is needed to further understand the substrate preferences in route selection. This study does support evidence for behavioral changes in regard to visual detection by predators as seen in the significant difference in distance traveled between the night and day trials. The importance of vision for *Peromyscus maniculatus* predators is fairly unexplored research area, but their behavioral adaptations against visual detection is reason alone to further investigate this field.

## ACKNOWLEDGEMENTS

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## FIGURE LEGENDS

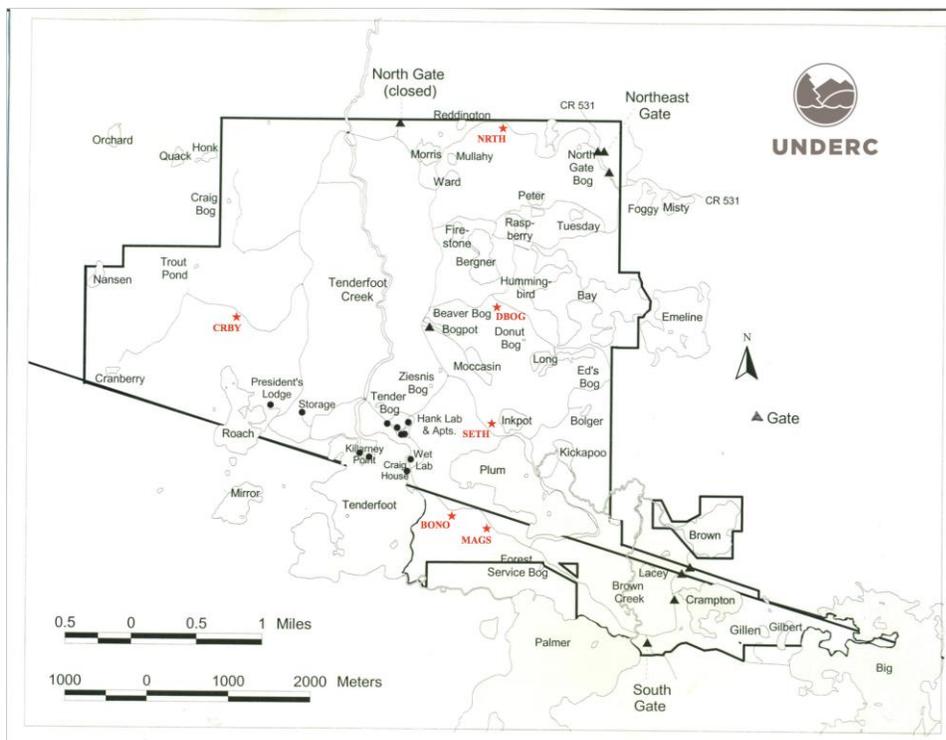
*Figure 1. The trapping grid and release locations of the Peromyscus maniculatus used in this study. All contained a mixed hardwood forest with little to no understory and shrub layer.*

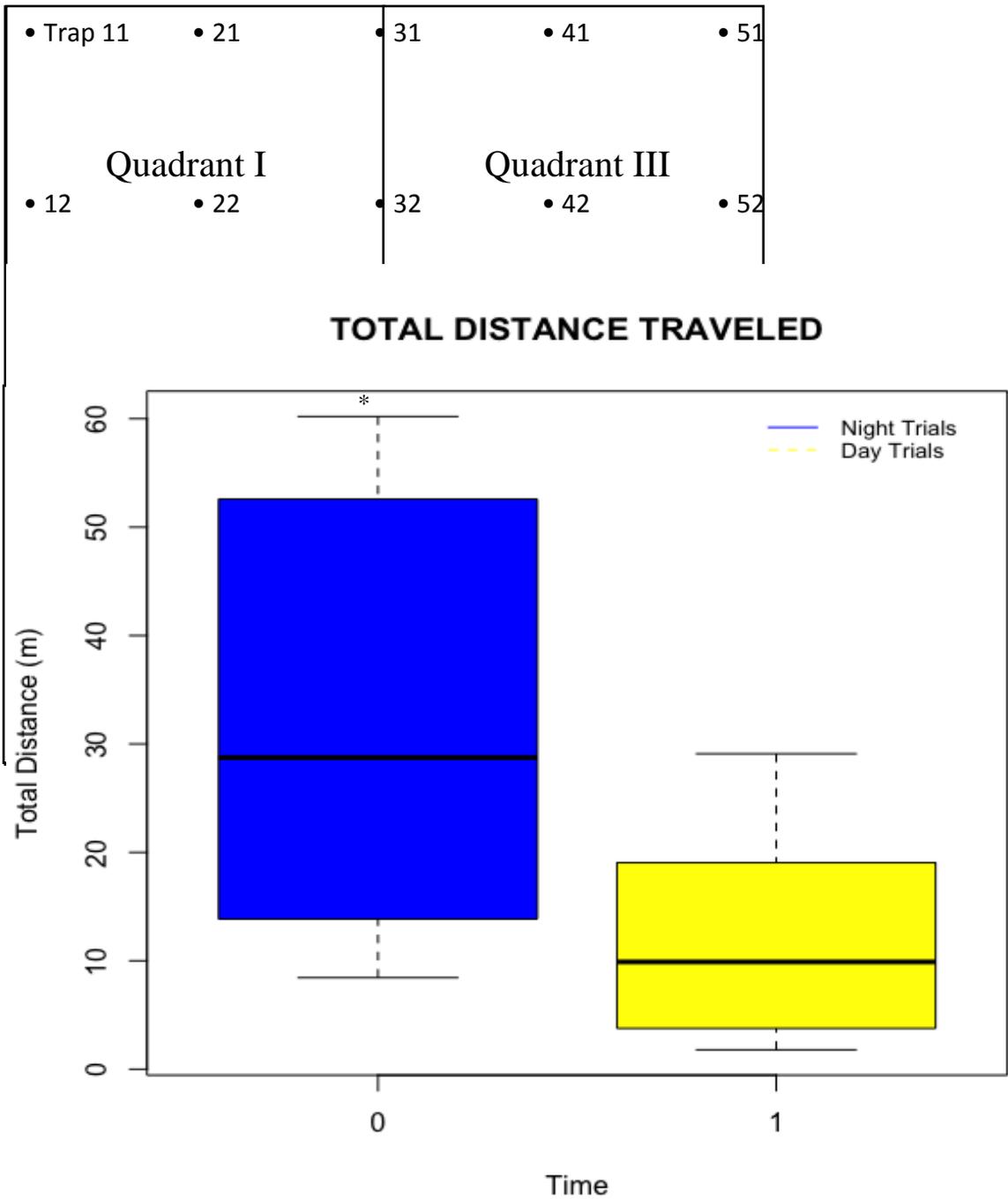
*Figure 2. A “full” trapping grid of 5 x 5 traps with 15 m spacing split into 4 quadrants (I-IV), marked with traps to further display the idea of the trapping grid. Half trapping grids would*

contain only quadrants I and II or I and III. The center points for each quadrant are as follows: I – 22, II – 24, III – 42, IV – 44. The center points were used as common release points for the *Peromyscus maniculatus* tracked in this study.

Figure 3. The total distance traveled of *Peromyscus maniculatus* in night and day trial settings.

The night trial ( $32.375 \text{ m} \pm 7.450$ ) deer mice traveled significantly farther than the day trial mice ( $12.040 \text{ m} \pm 3.576$ ;  $\chi^2 = 4.4118$ ,  $df = 1$ ,  $P = 0.036$ ), likely due to behavioral differences in avoiding visual detection by predators.





APPENDIX

Trial	Mouse Tag	Species	Time	Date	Sex	Total Distance (m)	Total Deviations	Proportion on LL	Proportion on CWD	Home	Grid	Wet	Proportion exposed
1	8223	Pman	1	7/12/19	1	13.4	28	0.30	0.70	1	BONO	0	0.01
2	7505	Pman	1	7/12/19	0	3.085	13	0.76	0.24	1	BONO	1	1.00
3	8107	Pman	0	7/12/19	1	14.776	26	0.62	0.38	1	BONO	1	0.99
4	8225	Pman	0	7/12/19	1	12.912	29	1.00	0.00	1	BONO	1	0.53
5	8227	Pman	0	7/13/19	0	8.445	12	0.92	0.08	1	BONO	0	0.66

7	8255	Pman	1	7/15/19	0	24.072	22	0.61	0.39	1	DBOG	0	0.60
8	8253	Pman	0	7/15/19	1	60.202	50	0.86	0.14	0	DBOG	1	0.97
9	8257	Pman	1	7/16/19	1	4.451	10	0.89	0.11	1	NRTH	0	0.96
10	8135	Pman	0	7/16/19	1	18.058	16	0.91	0.09	1	DBOG	0	0.85
11	8269	Pman	1	7/17/19	0	1.788	7	0.84	0.16	0	SETH	0	1.00
12	8277	Pman	1	7/17/19	1	6.401	10	0.90	0.10	1	MAGS	0	0.88
13	8271	Pman	0	7/17/19	1	51.928	50	0.93	0.07	0	MAGS	0	0.94
14	8285	Pman	1	7/19/19	1	29.096	25	0.72	0.28	1	CRBY	1	0.79
15	8137	Pman	1	7/19/19	1	14.026	11	0.75	0.25	1	CRBY	1	0.71
16	8281	Pman	0	7/19/19	1	39.428	48	0.53	0.47	1	CRBY	1	0.55
17	8287	Pman	0	7/19/19	1	53.251	41	0.37	0.63	0	CRBY	1	0.50

Collection of all data; where Pman is *Peromyscus maniculatus*; in “time” 0 is night and 1 is day; in “sex” 0 is female and 1 is male; in “Proportion on LL” where LL is leaf litter; in “home” where 1 is the trial ended at a definite location and 0 there was no discernible end location; and in “wet” where 0 is dry and 1 is damp conditions.

Trial 1

flag	distance (cm)	degree	substrate (cm)	sub. (cm)	light	cover
1	20	274	LL	2.5	6	0
2	20	310	LL	2.5	6	0
3	20	314	LO	4.5	6	0
4	100	280	LO	5.5	6	0
5	20	272	LO	6.5	6	0
6	40	220	LO	7.3	6	0
7	20	254	LL	3	3	1
8	20	166	LL	3	3	1
9	20	210	LL	3	8	0
10	20	184	LL	3	8	0
11	20	30	LL	3	8	0
12	20	352	LL	3	0	1
13	20	122	LL	3	0	0
14	20	18	LL	3	0	0
15	20	320	LL	3	2	2
16	20	358	LL	3	2	2
17	340	46	LO	9	6	0
18	400	78	LO	3.5	6	0
19	20	40	LO	6.6	6	0
20	20	98	LL	2	6	0
21	20	56	LL	2	6	0
22	20	90	LL	2	6	0
23	20	150	LL	2	6	0
24	20	104	LL	2	6	0
25	20	126	LL	2	6	0
26	20	156	LL	2	6	0
27	20	4	LL	2	6	0
28	0	0	stump (50d)		0	1

Trial 2

flag	distance (cm)	degree	substrate type	sub. (cm)	light	cover
1	16.4	98	LL	1.7	3	0
2	12.8	212	LL	1.7	3	0
3	42.3	88	LL	1.7	3	0
4	25.5	98	LL	1.7	3	0
5	9.6	138	LL	1.7	3	0
6	58	32	LO	3.6	3	0
7	19.4	40	LL	2.2	3	0
8	41.9	336	LL	2.2	3	0
9	26.6	74	LL	2.2	3	0
10	15.4	32	T	7	3	0
11	20.8	88	LL	3.2	3	0
12	19.8	98	LL	3.2	3	0
13	0	0	stump (50d)		0	1

Trial 3

flag	distance (cm)	degree	substrate type	sub. (cm)	light	cover
1	39.7	38	LL	2.2	0	0
2	46.8	350	LL	2.2	0	0
3	52.4	30	LL	2.2	0	0
4	14.3	64	LL	2.2	0	0
5	23.5	328	LL	2.2	0	0
6	75.7	21	LL	2.2	0	0
7	49.8	354	LL	2.2	0	0
8	19.5	22	LL	2.2	0	0
9	56.8	38	LL	2.2	0	0
10	15.7	84	LL	2.2	0	0
11	84.4	26	LL	2.2	0	0
12	26.7	108	LO	6.5	0	0
13	32.1	38	LL	1.7	0	0
14	206.2	44	LL	1.7	0	0
15	69.2	348	LL	1.7	0	0
16	47.4	46	LO	7.7	0	0
17	44	78	LO	14.5	0	0
18	44.6	6	LO	8.5	0	0
19	58.9	66	LL	2.6	0	0
20	26.6	140	LL	2.6	0	0
21	62	164	LO	2.8	0	0
22	26.8	209	LO	4.8	0	0
23	11	128	LL	3.4	0	1
24	310.6	123	LO	6.4	0	0
25	32.9	64	LL	2.8	0	0
26	0	0	branch pile (60d)		0	1

Trial 4

flag	distance (cm)	degree	substrate type	sub. (cm)	light	cover
1	26.4	96	LL	1.3	0	0
2	14.9	178	LL	1.3	0	0
3	16.6	48	LL	1.3	0	0
4	32.7	98	LL	1.3	0	0
5	18.4	227	LL	1.3	0	0
6	14.1	290	LL	1.3	0	0
7	28.7	111	LL	1.3	0	0
8	11.8	160	LL	1.3	0	0
9	10.5	281	LL	1.3	0	0
10	30.8	20	LL	1.3	0	0
11	19.4	63	LL	1.3	0	0
12	46.4	21	LL	1.3	0	0
13	62.3	101	LL	1.3	0	0
14	110.3	86	LL	1.3	0	2
15	54.2	62	LL	1.3	0	2
16	27.6	135	LL	1.3	0	0
17	44.2	94	LL	1.3	0	0
18	59.1	31	LL	1.3	0	0
19	60.2	112	LL	1.3	0	0
20	12.3	76	LL	1.3	0	2
21	36.1	118	LL	1.3	0	2
22	90.9	340	LL	1.3	0	2
23	157.6	59	LL	1.3	0	0
24	126.9	84	LL	1.3	0	2
25	50.8	350	LL	1.3	0	2
26	56.3	36	LL	1.3	0	1
27	32.6	98	LL	1.3	0	1
28	39.1	42	LL	1.3	0	1
29	0	0	wood pile (60d)		0	1

Trial 5

flag	distance (cm)	degree	substrate (cm)	sub. (cm)	light	cover
1	19	116	LL	0.4	0	0
2	399	192	LL	0.4	0	0
3	7.1	252	LL	0.4	0	0
4	12.6	46	LL	0.4	0	0
5	20	120	LL	0.4	0	0
6	98.3	178	LL	0.4	0	0
7	45.9	129	LL	0.8	0	2
8	70.9	160	LL	0.8	0	2
9	105.7	183	LL	0.8	0	2
11	24.7	233	LO	1.1	0	2
12	41.3	196	T	13.5	0	2
13	0	0	tree (174d)		0	0

Trial 6

flag	distance (cm)	degree	substrate (cm)	sub. (cm)	light	cover
1	20.5	14	LO	19	9	0
2	50	268	LL	1.1	9	0
3	94	284	LL	2.1	9	0
4	99.2	249	LL	3.1	9	0
5	50.8	169	LL	4.1	9	0
6	28.2	121	LO	18.7	9	0
7	54.9	95	LL	1.9	9	0
8	30.2	60	LL	2.9	9	0
9	17.3	143	LL	3.9	0	1
10	0	0	tree (245d)		9	0

Trial 7

flag	distance (cm)	degree	substrate (cm)	sub. (cm)	light	cover
1	36	39	LL	1	7	0
2	152.6	73	LL	1	7	0
3	134	91	LL	1	7	0
4	89.6	30	LL	1	7	0
5	59	38	LO	6.6	7	0
6	19.4	78	LL	0.6	7	0
7	214	98	LL	0.6	7	0
8	384	86	LO	6.7	5	2
9	56.8	60	LL	1.2	5	2
10	54.4	129	LO	4.3	5	2
11	122.6	79	LO	2.3	5	2
12	17.3	85	LL	0.5	5	2
13	159.8	92	LO	5.6	5	2
14	152.6	26	LL	0.4	7	0
15	134	356	LL	0.4	7	0
16	89.6	98	LL	0.4	7	0
17	59	23	LO	2	7	0
18	63.2	25	LL	0.4	5	2
19	112.1	77	LL	1.4	5	2
20	206	24	LL	2.4	7	0
21	91.2	83	LO	9.4	7	0
22	0	0	hollow log (63d)		0	1

Trial 8

flag	distance (cm)	degree	substrate (cm)	sub. (cm)	light	cover
1	54.2	26	LL	0.4	0	0
2	5.8	270	LL	0.4	0	0
3	68	327	LL	0.4	0	0
4	71.8	7	LL	1.2	0	0
5	23.2	283	LL	1.2	0	0
6	252.4	334	LL	1.2	0	0
7	36.6	267	LL	1.2	0	0
8	276.4	355	LL	1.2	0	0
9	59.2	297	LL	1.2	0	0
10	152.8	352	LL	1.2	0	0
11	70.6	31	LL	1.2	0	0
12	109.2	330	LL	1.2	0	0
13	146	358	LL	1.2	0	0
14	99.8	326	LL	1.2	0	0
15	75.6	286	LL	1.2	0	0
16	144.2	284	LL	1.2	0	0
17	80.8	162	LL	1.2	0	0
18	94	84	LL	1.2	0	0
19	141.2	276	LL	1.2	0	0
20	126	334	LL	1.2	0	0
21	345.4	284	LL	1.2	0	0
22	90.8	16	LL	1.2	0	0
23	254.8	65	LL	1.2	0	0
24	171.2	128	LL	1.2	0	0
25	159.4	210	LL	1.2	0	0
26	43.8	158	LL	1.2	0	0
27	85.4	210	LO	4.6	0	0
28	247.6	219	LL	0.8	0	0
29	144.8	275	LL	0.8	0	0
30	124.6	199	LL	0.8	0	0
31	25	120	LL	0.8	0	0
32	209.2	172	LL	0.8	0	0
33	87.2	158	LL	0.8	0	0
34	48.8	204	LL	0.8	0	0
35	122.2	248	LO	6.7	0	0
36	113.4	276	LL	0.2	0	1
37	90.8	66	LO	5	0	0
38	46.2	140	LL	0.7	0	0
39	55.8	218	LO	4.8	0	0
40	96.8	276	LL	0.2	0	1
41	224.6	140	LL	1	0	0
42	177.8	8	LL	1	0	0
43	170.8	30	LL	1	0	0
44	264.2	88	LO	6.3	0	0
45	209.6	93	LO	5.4	0	0
46	42.4	143	LL	0.9	0	0
47	54.6	85	LL	1.9	0	0
48	83.4	147	LL	2.9	0	0
49	141.8	290	LL	3.9	0	0
50	0	0	no discernible path		0	0

Trial 9

flag	distance (cm)	degree	substrate (cm)	sub. (cm)	light	cover
1	23.9	141	LL	2	0	0
2	67	178	LL	2	0	0
3	80.2	192	LL	2	0	0
4	96.1	224	LL	2	0	0
5	49.6	192	LO	2	0	0
6	67.8	202	LL	2.4	0	0
7	98	257	LL	2.4	0	0
8	341.2	193	LL	2.4	0	0
9	80.4	245	LL	2.4	0	0
10	303	321	LL	2.4	0	0
11	100.8	245	LL	2.4	0	0
12	270.4	292	LL	2.4	0	2
13	85.8	331	LL	2.4	0	0
14	108.2	237	LO	7.6	0	0
15	33.4	152	LL	1.8	0	0
16	0	0	climbed tree (252d)		0	0

Trial 10

flag	distance (cm)	degree	substrate (cm)	sub. (cm)	light	cover
1	32	296	LL	4	12	0
2	33.8	249	LL	4	12	0
3	23.4	229	LO	6.6	12	0
4	25.2	278	LL	0.4	12	0
5	59	239	LL	0.4	12	0
6	5.4	30	T	36.3	12	0
7	0	0	stationary on tr	36.2	12	0

Trial 11

flag	distance (cm)	degree	substrate	sub. (cm)	light	cover
1	21.2	96	LL	2	12	0
2	20.8	257	LL	2	12	0
3	43.1	118	LL	2	12	0
4	45	75	LL	2	12	0
5	79.4	130	LL	2	5	2
6	157	124	LL	2	12	0
7	66.4	147	LL	2	12	0
8	142.2	150	LL	2	12	0
9	65	228	T	32	12	0
10	0	0	stump (130d)		0	1

Trial 12

flag	distance (cm)	degree	substrate	sub. (cm)	light	cover
1	31.3	166	LL	1.5	0	0
2	25.2	247	LL	1.5	0	0
3	44.1	150	LL	1.5	0	0
4	25.3	281	LL	1.5	0	2
5	115.2	207	LL	1.5	0	0
6	32.5	122	LL	1.5	0	0
7	17	48	LL	1.5	0	0
8	110.4	150	LL	1.5	0	0
9	177	100	LL	1.5	0	0
10	50.2	168	LL	1.5	0	0
11	213.6	124	LL	1.5	0	0
12	268.2	114	LL	1.5	0	0
13	127	36	LL	1.5	0	0
14	100.2	174	LL	1.5	0	0
15	61	139	LL	1.5	0	2
16	218.6	206	LL	1.5	0	0
17	24.4	238	LL	1.5	0	2
18	214	184	LL	1.5	0	0
19	155.2	78	LO	3	0	0
20	106.4	272	LO	4	0	0
21	56.2	210	LL	9	0	0
22	36.7	254	LL	10	0	0
23	42	162	LO	11.9	0	0
24	42.3	338	LO	12.9	0	0
25	298	233	LL	5	0	0

Trial 13

26	97.2	272	LL	5	0	0
27	98	200	LL	5	0	0
28	109.8	268	LL	5	0	0
29	65.4	190	LL	5	0	0
30	207.2	244	LL	5	0	0
31	208.4	296	LL	5	0	0
32	85.6	235	LL	5	0	0
33	89	156	LL	5	0	0
34	59.2	10	LL	5	0	2
35	91.4	115	LL	5	0	0
36	111	10	LL	5	0	0
37	182	70	LL	5	0	0
38	67	50	LL	5	0	2
39	189.2	247	LL	5	0	0
40	75.2	260	LL	5	0	0
41	87.8	43	LL	5	0	0
42	54.6	229	LL	5	0	0
43	61.8	300	LL	5	0	0
44	45.4	170	LL	5	0	0
45	111	150	LL	5	0	0
46	199.4	248	LL	5	0	0
47	165.2	335	LL	5	0	0
48	59.8	275	LL	5	0	0
49	80.2	154	LL	5	0	2
50	0	0	no discernible path		0	0

Trial 14

flag	distance (cm)	degree	substrate	sub. (cm)	light	cover
1	17.2	237	LL	2.5	14	0
2	25.2	81	LL	2.5	14	0
3	26.4	25	LL	2.5	14	0
4	246.6	79	LL	2.5	14	0
5	100.2	129	LL	2.5	14	0
6	32	82	LL	2.5	8	2
7	168	112	LL	2.5	14	0
8	101.2	50	LL	2.5	8	2
9	160.6	44	LL	2.5	14	0
10	167.6	129	LO	8.2	14	0
11	65	24	LL	3	14	0
12	189.4	88	LO	4.1	14	0
13	42.8	258	LL	3	14	0
14	244.2	14	LO	10.9	8	2
15	342	32	LL	2.5	14	0
16	131	10	LL	2.5	14	0
17	94.4	63	LL	2.5	14	0
18	53.8	84	LL	2.5	14	0
19	160.6	160	LO	12.2	14	0
20	228.4	106	LL	2	8	2
22	131.4	40	LL	2	14	0
23	61.4	10	LO	7.7	14	0
24	93.2	41	LL	2	14	0
25	27	126	LL	2	14	0
26	0	0	climbed hollow tree (63)			1

Trial 15

flag	distance (cm)	degree	substrate	sub. (cm)	light	cover
1	81.4	326	LL	5	14	0
2	42.8	22	LL	5	14	0
3	181.2	321	LL	5	8	2
4	214.6	65	LL	5	14	0
5	172.2	85	LL	5	14	0
6	135.2	15	LO	4.9	14	0
7	66	25	LL	4	14	0
8	220	10	LL	4	8	2
9	74.8	155	LL	4	14	0
10	214.4	123	LO	10.7	14	0
11	0	0	under log (75)		0	1

Trial 16

flag	distance (cm)	degree	substrate	sub. (cm)	light	cover
1	41.7	204	LL	3	0	0
2	23.1	290	LL	3	0	0
3	61	178	LL	3	0	0
4	29.8	86	LO	3.7	0	0
5	50.8	40	LL	2.5	0	0
6	25	342	LO	1.4	0	0
7	54.6	10	LL	2.4	0	0
8	128.4	81	LL	2.4	0	2
9	44.7	310	LL	2.4	0	0
10	149.4	70	LL	2.4	0	0
11	201.2	314	LO	3	0	0
12	58.8	11	LL	4	0	0
13	293.8	281	LO	7.7	0	0
14	37.5	434	LO	6.9	0	0
15	49.2	7	LL	5.5	0	2
16	64.8	81	LO	6.9	0	0
18	22.8	104	LL	5.4	0	0
19	21.2	59	LL	4.5	0	0
20	28.8	73	LO	6.4	0	0
21	23.7	42	LL	4.5	0	0
22	61.2	74	LO	5.4	0	0
23	406	30	LO	5	0	0
24	110.8	47	LL	3.9	0	0
25	58.8	304	LL	3.9	0	0
26	62.8	62	LO	6.1	0	0
27	45.4	5	LL	4.2	0	0
28	130	48	LL	4.2	0	0
29	100.8	79	LL	4.2	0	2
30	107	67	LO	2.6	0	2
31	26.9	31	LL	4	0	0
32	26.4	103	LL	4	0	0
33	26.8	150	LO	4.7	0	2
34	44.3	158	LL	5.2	0	2
35	32.4	110	LL	5.2	0	2
36	14.1	17	LL	5.2	0	2
37	113.4	67	LO	2.8	0	2
38	15.5	44	LL	8	0	2
39	72.8	110	LL	8	0	2
40	69.2	353	LO	2.5	0	2
41	111.4	153	LO	2.5	0	2
42	97.5	117	LL	2.5	0	2
43	200.2	34	LO	6.7	0	2
44	316.2	308	LL	5	0	2
45	25.8	318	LL	5	0	2
46	172	279	LL	5	0	2
47	63.8	340	LL	5	0	2
48	21	40	T	21	0	2
49	0	0	climbed tree (157)		0	2

Trial 17

flag	distance (cm)	degree	substrate	sub. (cm)	light	cover
1	31.1	118	LL	2	0	2
2	104.6	194	LL	2	0	2
3	24.5	150	LL	2	0	2
4	41	250	LO	3.5	0	2
5	26.7	165	LL	4.5	0	2
6	114.2	194	LL	4.5	0	2
7	31.7	185	LO	2.3	0	2
8	27.2	256	LL	5.2	0	2
9	208.4	170	LL	5.2	0	2
10	35.7	230	LL	5.2	0	0
11	208.8	167	LL	5.2	0	0
12	168.2	251	LL	5.2	0	0
13	234.4	298	LO	4.7	0	2
14	69.8	145	LO	23	0	0
15	262.2	244	LO	8.3	0	2
16	58.6	208	LL	4.2	0	0
17	139.4	240	LO	31	0	0
18	18.4	166	LO	9	0	0
19	31.4	124	LO	2.8	0	2
20	108.4	279	LL	2	0	2
21	588.4	233	LO	9.6	0	0
22	155.1	241	LO	6.9	0	0
23	40	143	LO	6.5	0	0
24	55.2	175	LO	55.2	0	0
25	32	176	LL	4.5	0	0
26	136.8	70	LO	9.5	0	0
27	77.2	151	LL	2.5	0	0
28	139.8	79	LL	2.5	0	2
29	697.8	175	LO	9.9	0	2
30	240.8	135	LO	4.8	0	2
31	15.8	206	LL	5	0	2
32	146.2	175	LO	3.4	0	2
33	127.4	51	LL	3.6	0	0
34	390.2	132	LO	7.1	0	0
35	105.4	201	LL	4	0	0
36	110.9	10	LL	4	0	0
37	38.4	88	LL	6.8	0	0
38	102.2	29	LO	2.8	0	0
39	72.4	93	LL	2.5	0	
40	108.4	59	LL	2.5	0	2
41	0	0	no discernible path		0	0