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Newt Orientation After Displacement

Nolen Collazo

Biology Department
The University of North Carolina Asheville
One University Heights
Asheville, North Carolina 28804 USA

Faculty Mentor: Rebecca Hale

Abstract

This study aimed to see if *Notophthalmus viridescens viridescens*, the eastern red spotted newt, could orient towards their home pond following a short displacement. Previous studies on newt navigation have shown that newts have the ability to navigate home following displacement of up to 45 km. This species uses magnetoreception to navigate at these longer distances varying from 10-45 km; however, at shorter distances, such as 40 m, this mechanism might not be useful due to there being less spatial variation in the magnetic field. This study displaced newts 40 m, measured their initial orientation, and evaluated whether they oriented toward the pond or towards a specific cardinal direction. This was done in order to test whether newts have the ability to orient following a short displacement. The experiment took place at Sandy Bottom Preserve in Buncombe County, NC from May 19th, 2025, to June 23rd, 2025. The results of this study showed that there was no significant tendency to orient towards the pond or a specific cardinal direction. This study provides a solid experimental design for future studies into this topic and investigates how and why future research is needed to better understand newt orientation.

Introduction

Homing is a complex behavior seen in a variety of different animals and is essential for the survival of many. This behavior allows animals to return home after displacement by first orienting to their home site direction and navigating from their location to their home site. Home can be broadly defined as a previously known place, such as breeding ponds or feeding grounds. This behavior is shaped by internal factors, which include motivation, navigation, and mobile capacity. External factors, such as the availability of sensory cues and social drivers. As well as stochastic factors, such as predation and chance (Holyoak et al. 2008). Arthropods and all major groups of vertebrates have been shown to use homing to some degree.

At small spatial scales, crayfish, which move short distances from their burrows, use path integration as a homing mechanism, allowing for them to return to the burrow using the same path in which they left it. Even when their burrows were destroyed, they continue to return to the original site of their burrow (Kamran et al. 2018). This could indicate that crayfish use landmark cues or a spatial map in order to return back to their burrow and not cues from the burrow itself (Kamran et al. 2018). Lizards are another animal that has shown the ability to navigate and return to their home site following displacement. Ellis-Quinn and Simony (1991) showed that the parietal eye in the lizard *Sceloporus jarrovi* contains a key receptor for following celestial cues and when covered, these lizards could not orient towards home using only their lateral eyes. This species of lizard incorporates celestial cues into a time-compensated compass mechanism to navigate home after displacement (Ellis-Quinn and Simony 1991). Mice have also been known to use homing mechanisms in order to navigate. Mice homing success is inversely distance dependent and olfactory and visual cues are both used in their navigation (Cooke and Terman 1977).

At much larger spatial scales, multiple fish species have been shown to home over vast distances in a variety of different habitats. Several species of juvenile reef fish use olfactory and/or visual cues, depending on the distance of displacement to move between breeding and feeding habitats (Streit and Bellwood 2017). Both freshwater and sea turtles exhibit the ability to navigate to home ponds or breeding sites. Freshwater turtles such as the painted turtle, *Chrysemys picta*, have been shown to use chemical signals, spatial memory, and sun compass navigation mechanisms in order to return to their home site after artificial displacement (Xiao et al. 2021), whereas sea turtles have been shown to rely primarily on a geomagnetic map to navigate hundreds of kilometers or more to go between foresting grounds and nesting beaches (Lohmann et al. 2022). Camels which range widely between desert habitats are another animal that is known to use homing behavior throughout their lives. Camels use path integration in order to return to a particular site after artificial displacement and impairing their olfactory, visual, and auditory senses does not impact their ability to home but disorienting them during displacement does (Alyan 2021).

Orientation and navigation have been extensively studied in amphibians. Amphibians navigate annually between aquatic breeding habitat and upland sites where they feed and burrow. However, homing in amphibians is not only motivated by breeding, as toads continue to navigate home even after breeding season when they are displaced. They do this using primarily celestial orientation and spatial memory (Jreidini and Green 2022).

Notophthalmus viridescens viridescens, the eastern red spotted newt, lives in both terrestrial and aquatic environments depending on their life stage and the time of year, and there have been multiple studies on their homing behavior. They are commonly found in the eastern United States and are carnivorous, making them good at maintaining mosquito populations by feeding on mosquito larvae. They are a known ectotherm that have been shown to thermoregulate their body temperature (Berner and Bessay 2006). These adult newts also can increase their lateral tail area in their aquatic stage of life and decrease it during their terrestrial stage to increase movement efficiency. This change in tail size positively correlates to aquatic movement but does not affect terrestrial movement (Brossman et al. 2013). During their terrestrial eft life stage, which is a juvenile life stage where they leave the breeding pond, efts move to shade and decrease activity when at risk of desiccation. They also use chemical cues to find food and other efts in order to huddle and reduce the rate at which they lose water. When at risk of predation, these efts reduce their activity and avoid alarm cues from other newts (Rohr and Madison 2003). They are also known to produce a potent neurotoxin that makes them able to defend themselves from predators.

In a study done on *Notophthalmus viridescens*, the authors found that newts aligned to certain magnetic field lines and that all the newts they experimented on were oriented toward East or West cardinal directions, rather than toward a specific location in the landscape (Schlegel 2006). Newts possess two separate magnetoreception pathways when navigating: one that responds only to the axis of the magnetic field, and another that responds to the polarity of the magnetic field (Phillips 1986). These findings led the authors to examine whether newts use a “magnetic map” in order to home when displaced from their breeding pond. The authors concluded that newts do use a magnetic map in order to home and their findings support two critical predictions of the magnetic map hypothesis, that magnetic inclination affected homing direction but had no effect on shoreward magnetic compass orientation (Fischer et al. 2001). Another study that confirms that newts use a “magnetic map” showed that magnetic inclination is also used to derive map information (Phillips et al. 2002). While most studies focus on newts’ ability to use geomagnetic information in homing, one study focused on how long it took for *Notophthalmus viridescens* to learn the direction of the y-axis, which is the axis perpendicular to the shoreline. The authors concluded that it takes newts 12 to 16 hours to orient towards the y-axis with respect to the geomagnetic field (Phillips 1986). It has been discovered that newts use extraocular photoreceptors in their light-dependent magnetic orientation. These photoreceptors are thought to be located in the pineal complex or deeper in the brain, such as the hypothalamus (Deutschlander et al. 1999).

The goal of this study was to see if *Notophthalmus viridescens viridescens*, the eastern red spotted newt, exhibits homing behavior after being displaced from their pond. Most studies of eastern newts have focused on what type of cues and mechanisms they use and have tested newts displaced at 10-45 km. In contrast, I focus not on how they navigate but on whether they can orient following a shorter displacement of approximately 40 m, where geomagnetic and celestial cues may be less useful and path integration as well as landmark and olfactory cues may be more useful. I also examine whether animals that choose their orientation more quickly do so more accurately. I predict that eastern red spotted newts do have the capacity to orient towards their home pond over short distances and that a shorter time to orient is associated with a more accurate orientation.

Methods

Study Site and Animal Collection

The experiment was designed to look at the orientation of *Notophthalmus viridescens viridescens* after displacement from their home pond and whether they oriented toward the pond. The study also examined how long it took the newts to make a decision on which direction they would go. The experiment was conducted at Sandy Bottom Preserve (Buncombe County, NC) on 5 separate days between May 19th 2025 and June 23rd 2025. All newts were collected in the aquatic adult stage of life. Three trials took place, one at each displacement site, with each newt. Every day, the site at which the first trial occurred was rotated. The time of day was also recorded.

Experimental Design

Ortmann (Dreschler et al. 2010) and minnow (Crawford et al. 2023) traps were placed 24 hours before being checked for eastern red spotted newts. Newts were extracted from traps and placed in a bucket filled with pond water. Plastic kiddie pools (1 m in diameter) marked in the center with a 20 cm radius circle (Fig. 1) were wiped with a sponge dipped in pond water to remove chemical cues that might interfere with the newts' orientation. These pools were set approximately 40 m away from the pond, one to the south of the pond near a road, one to the east of the pond in the forest, and one to the west of the pond on a hill (Fig. 2).

Between May 19th 2025 and June 23rd 2025, seven newts were tested for orientation behavior at each of the three displacement sites. Between trials, I carried the animals back to the middle of the pond before moving to the next displacement site. This ensured that if the animals were using path integration, they would tend to move directly back toward the pond - the last leg of their displacement path. The bearings from each displacement site to the pond were 313° from Road to pond, 280° from Forest to pond, and 40° from Hill to pond. For every trial, each newt was placed in the center of a kiddie pool and covered with a plastic container for 3 minutes. The newt's head was oriented randomly before the cup was placed over it. After 3 minutes of acclimation, the newt was uncovered and observed for 15 minutes or until the newt crossed the 20 cm radius circle. The orientation was recorded as the direction from the center of the pool to the point at which it crossed the circle as well as the time it took for the newt to cross the line. No newts took longer than 15 minutes to cross the line.

Data Analysis

Data analysis was performed using circular statistics in R (R Core Team 2025). In R, each bearing was first converted into a unit vector with a magnitude of 1 and x and y coordinates representing direction. Bearings were analyzed in their raw form to test for a tendency to move in a particular cardinal direction. Bearings were then converted to deviations from the pond direction and analyzed for pondward orientation. Both analyses evaluated whether bearings were significantly clumped, using a Rayleigh test in the R packages circular (Agostinelli & Lund 2025) and CircStats (Lund & Agostinelli 2025). The Rayleigh test evaluates the mean vector's magnitude and the greater its magnitude (range 0 - 1.0), the more clumped the bearings. The mean vector's direction and its 95% confidence interval (CI) were then determined to assess whether orientations were in the predicted direction. Because each newt's bearing was converted to a deviation from the pond direction, a 95% CI overlap with 0° would indicate orientation toward the pond.

Additionally, R was used to examine the relationship between bearing deviation and latency to make a decision, using a Spearman correlation test using the stats package of R.

Figure 1. Plastic kiddie pool marked with a 20 cm radius circle and plastic container that was used to cover newts.

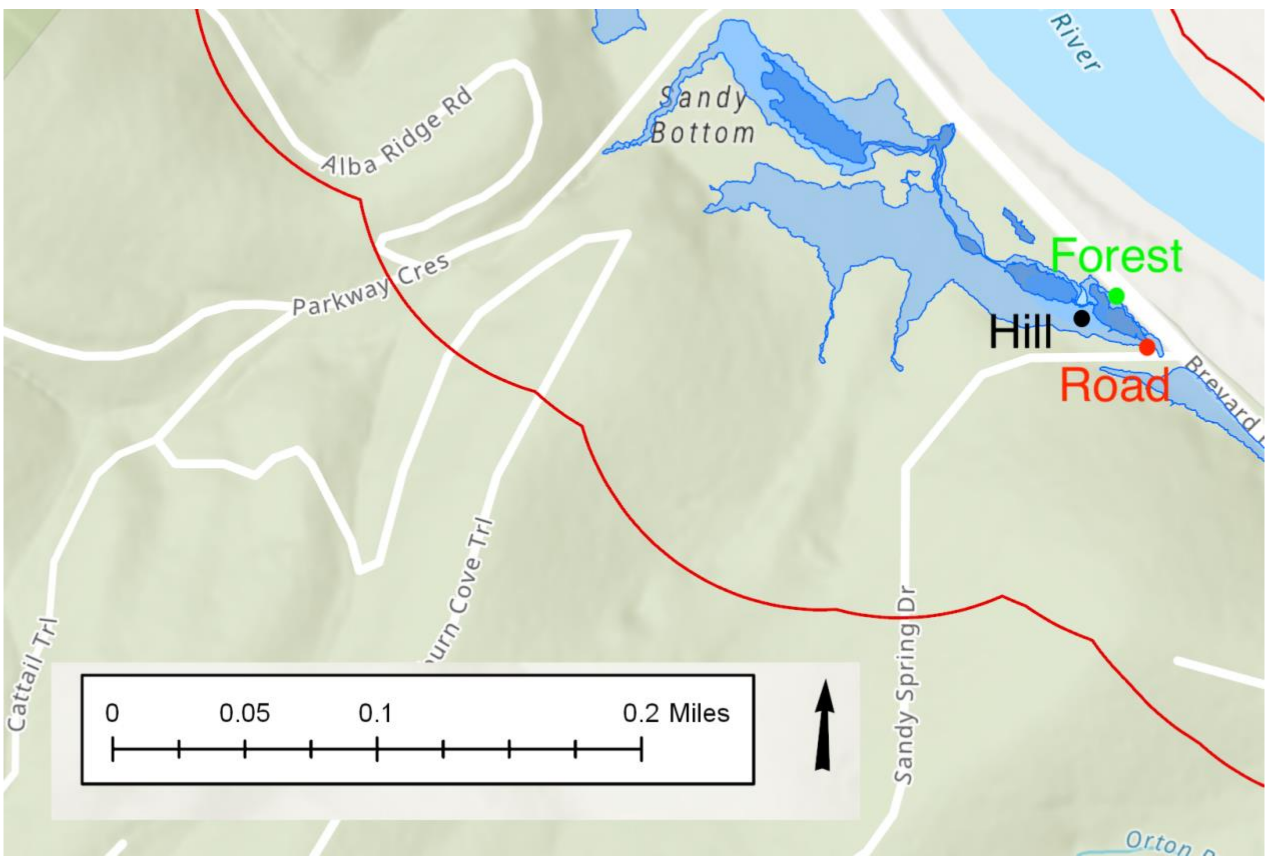

Figure 2. Map of Sandy Bottom Preserve and locations where trials took place. The areas with standing water are visible as dark blue. The light blue area indicates delineated wetland habitat.

Results

All animals that were tested made their decision in less than 15 minutes. The mean time it took the animals to make their decision and reach the 20 cm mark was 112 ± 126 seconds.

The Rayleigh test for assessing animal bearings in relation to pond direction showed a significant tendency for animals to orient +86.7° (95% CI: 51.1, 119.7) from the pond in the road displacement site ($r = 0.76$, $N = 7$, $p = 0.01$; Fig. 3). Animals showed no tendency to orient in a particular direction in the hill displacement site with a mean direction of +58.0° (95% CI: 23.7, 111.1) from the pond ($r = 0.61$, $N = 7$, $p = 0.07$; Fig. 3). Also, animals showed no tendency to orient in a particular direction in the forest displacement site with a mean direction of +42.0° (95% CI: 9.47, 105.7) from the pond ($r = 0.59$, $N = 7$, $p = 0.08$; Fig. 3).

The Rayleigh test for assessing animal bearings in relation to cardinal direction showed no tendency for animals to orient towards a particular cardinal direction ($r = 0.293$, $N = 21$, $p = 0.163$), with a mean direction $\theta = 7.9°$ (95% CI: -60.16, 83.65) from true North (Fig. 4).

The Spearman rank correlation tests for comparing bearing deviation with latency showed no relationship between bearing deviation from the pond and latency to orient in each of the animals 3 separate trials (Trial 1- $S = 48.937$, $p = 0.7876$, $\rho = 0.126$; Trial 2- $S = 50$, $p = 0.8397$, $\rho = 0.107$; Trial 3- $S = 48$, $p = 0.7825$, $\rho = 0.142$; $N = 7$; Fig. 5).

The Kruskal-Wallis rank sum test for comparing bearing deviation across treatments showed no effect of displacement location on animal orientation relative to the pond ($X^2_2 = 1.8558$, $p = 0.3954$; Fig. 6).

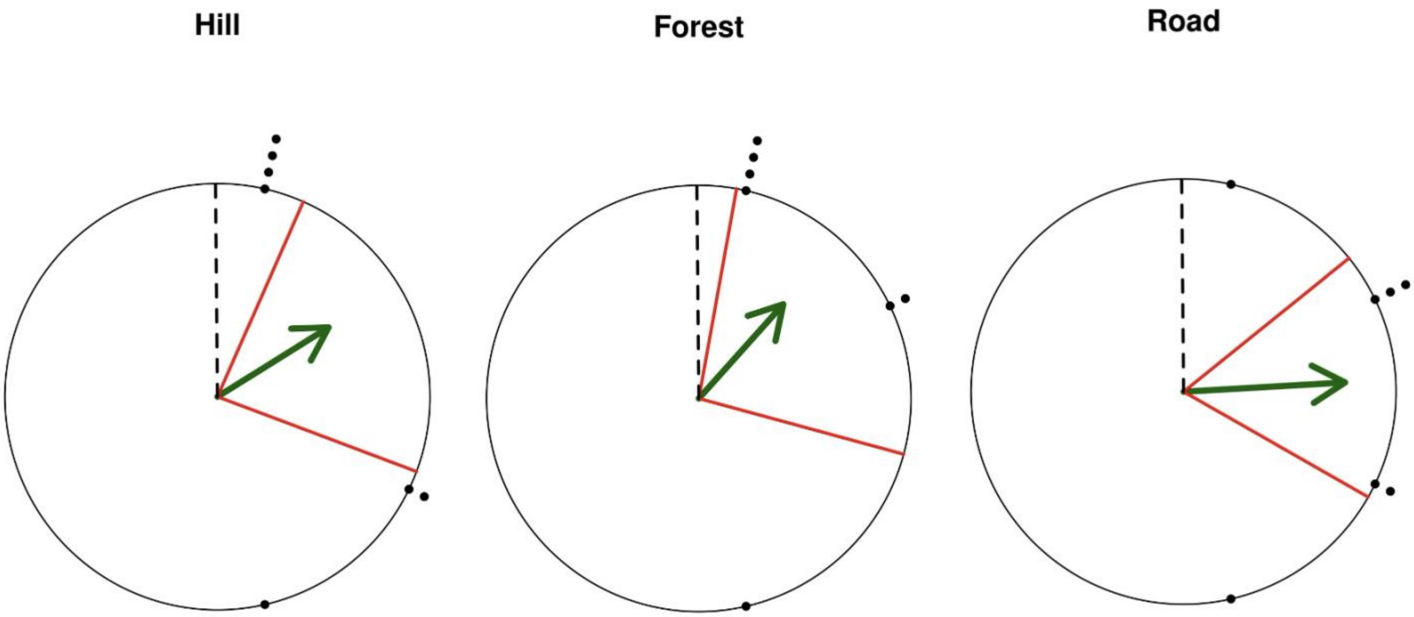

Figure 3. Vector representation of animal bearings in relation to pond direction, separated by each displacement site. The dashed line represents the pondward direction. The mean vector is represented by the green arrow, and the red lines represent the 95% confidence interval.

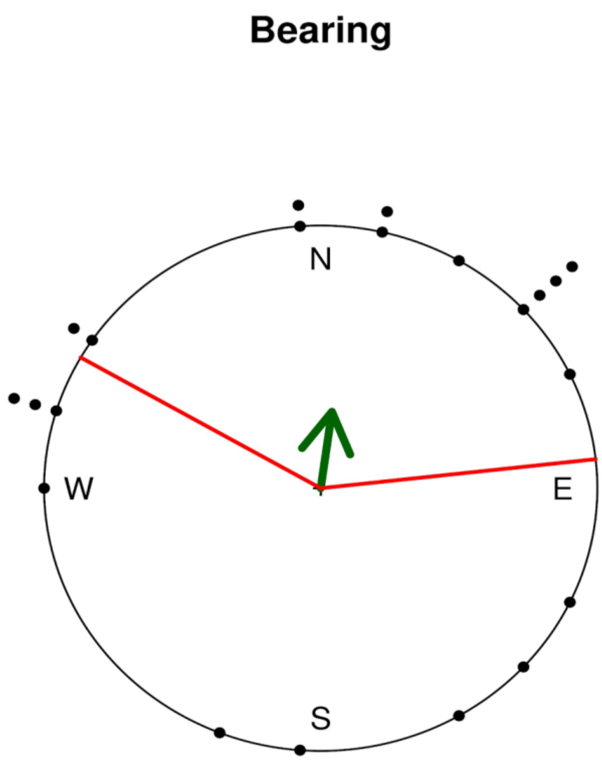

Figure 4. Vector representation of animal bearings in relation to cardinal direction. The mean vector (green arrow) direction is approximately 7°, with the red lines representing the 95% confidence interval and showing non-significant orientation towards a specific cardinal direction.

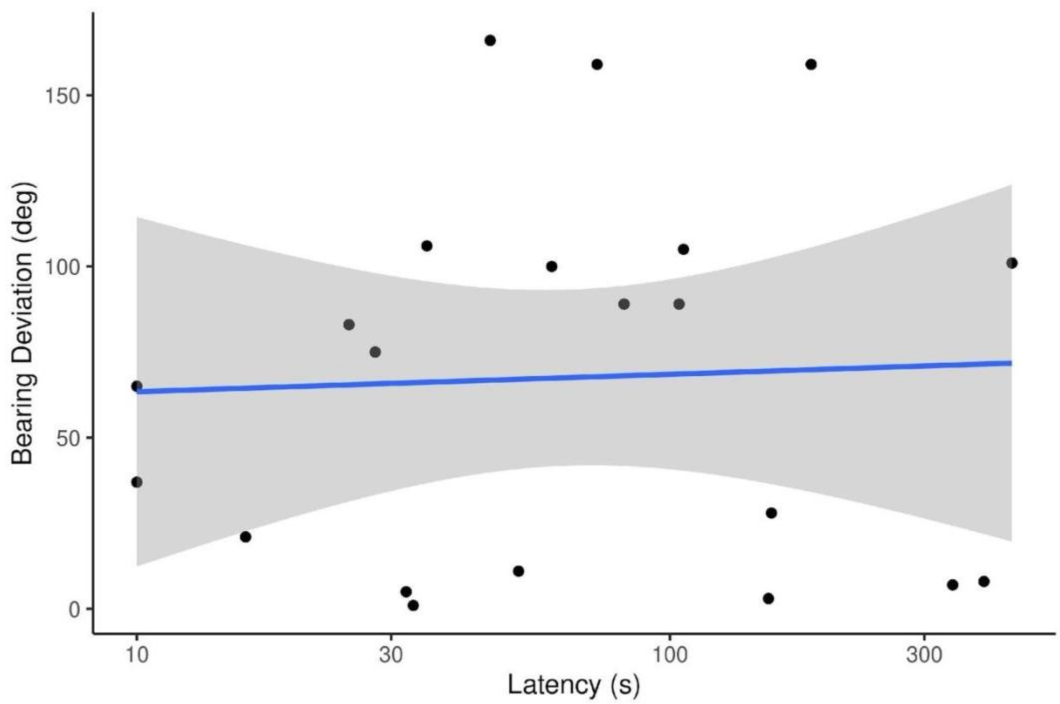

Figure 5. The relationship between the bearing deviation and latency of decision making with all trials pooled together. N = 7 newts, each tested 3 times. The shaded area is the 95% CI on the line of best fit.

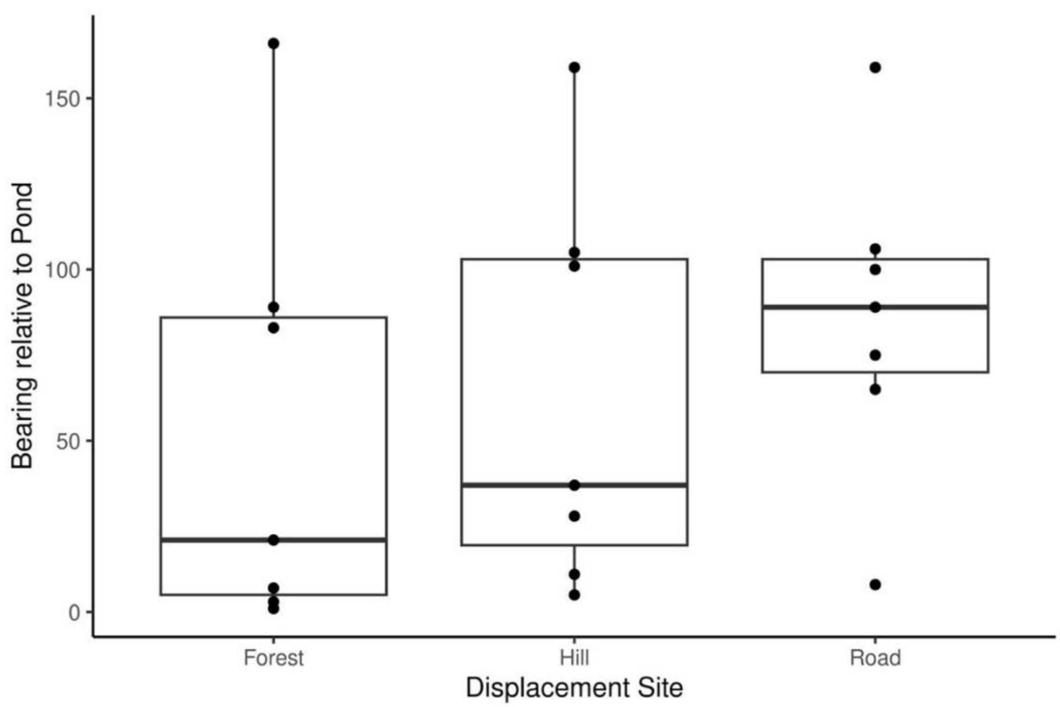

Figure 6. Newt orientation relative to the pond, separated by displacement location.

Discussion

Based on the data collected between May 19th 2025 and June 23rd 2025, newts do not show an ability to orient towards the pond following a displacement of approximately 40 m. Also, the time it took for the newts to orient and cross the 20 cm radius had no association with how accurate their direction was toward the home pond. Thus, I am able to reject my initial hypothesis that newts do have the capacity to orient home at short distances and time to orient is related to accuracy of orientation.

Newts not being able to orient towards the pond following a displacement of a short distance could be due to a variety of different factors. The displacement distance of 40 m that was chosen for this experiment could be too short, making the newts still feel like they are in the same geographical location as their home pond even when they are taken out of the water. Newts are known to use geomagnetic and celestial cues in order to navigate, so orienting after displacement of such a short distance would be more challenging due to there being only a slight (or no) change in geomagnetic or celestial cues at this spatial scale. This could explain why the newts did not orient in the predicted direction.

Another reason for the lack of home orientation behavior could be that the sample size of the experiment was too small. This experiment took place during the summer when the home pond was drying up and not many newts were able to be collected. Their motivation to return home may also have been overestimated due to the pond drying and perhaps a greater motivation in seeking a terrestrial habitat to survive the summer. This could be a reason for the wide range of bearings at the forest and hill displacement sites. The forest and hill displacement sites were in the middle of numerous trees while the road displacement site was bordering the trees.

This study sought to fill a gap on the topic of newt displacement over short distances. Learning more about this topic could help in understanding how newts are affected during natural or manmade disasters that cause a temporary short displacement. This study took place in an area heavily affected by Hurricane Helene, which was sure to have displaced numerous animals that lived in this wetland ecosystem, including the eastern red spotted newt.

For future studies into this topic, there are a few things I would like to do differently. I personally would like to achieve a greater sample size; this can be done by performing the experiment during the spring when these newts are more active in their home pond and might be more motivated to return home. Also, I would displace these newts at different distances from the pond. I would choose 40, 80, and 120 meters and compare their ability to orient at these 3 short distances, this will give a better idea of what distance newts start to accurately orient towards home. Due to newts using geomagnetic and celestial cues, I believe increasing the distance will allow for them to better use these mechanisms in order to orient themselves.

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