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WILDLIFE RESEARCH

Evaluating translocation strategies for box turtles in urbanising landscapes

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ABSTRACT

Context. Translocation is a common management strategy for wildlife populations, yet hard-release of reptiles, including box turtles (*Terrapene* spp.), has often proven ineffective due to homing attempts and wandering. Soft-release translocation has been presented as a possible method for mitigation of the negative effects of hard-release translocation, but studies incorporating standard soft-release strategies have produced mixed results and often see persistent homing attempts by soft-released study animals. **Aims.** The aim of this study was to examine long-term holding (>1 year) of box turtles at an off-site location prior to translocation as a means to reduce homing attempts and wandering commonly observed in immediate-release box turtles. **Methods.** We radiotracked translocated *Terrapene carolina triunguis* to compare movements of nine immediate-release box turtles and nine box turtles that had been maintained for >1 year at a nearby off-site holding facility (long-term holding) prior to a 750–1000 m translocation. **Key results.** Box turtles held long-term before a short-distance translocation moved significantly shorter distances each day post-release than immediate-release turtles. Turtles held long-term moved in non-directional, random orientations, whereas immediate-release turtles exhibited consistent directionality in movements back towards their initial capture (home) locations. **Conclusions.** Our results demonstrated that turtles held off-site remained within the translocation site more reliably than the immediate-release turtles, which had a higher tendency to home. **Implications.** Long-term holding of turtles prior to translocation could significantly reduce homing responses and wandering, thus increasing translocation efficacy while reducing intensity of post-translocation management.

Keywords: habitat degradation, homing, radio telemetry, site fidelity, spatial ecology, *Terrapene carolina triunguis*, translocation, urbanisation, wildlife management.

Introduction

Habitat degradation as a consequence of urbanisation can have detrimental effects on wildlife, whether it be from direct landscape development or overall increase in human populations (Kapfer *et al.* 2013; Liu *et al.* 2016; Heinrichs *et al.* 2016). Millions of hectares of natural landscapes historically degraded by agricultural use or decades of fire suppression that remained suitable for many species are being further altered by the rapid increase in urban and residential development across the USA (Dodd 2002; Hutchinson *et al.* 2005; Hanberry 2019; Paterson *et al.* 2021). Roads now fragment populations across landscapes in small patches of habitat, often resulting in population declines or extirpation (Gibbons *et al.* 2000; Liu *et al.* 2016; Paterson *et al.* 2021). Globally, reptile species have experienced severe consequences from habitat loss caused by urbanisation (Gibbons *et al.* 2000; Paterson *et al.* 2021; Cox *et al.* 2022), with approximately 21% of reptile species currently listed on the International Union for Conservation of Nature (IUCN) Red List as being threatened with extinction (Cox *et al.* 2022). Consequently, novel methods are needed to help conserve reptile populations in urbanising landscapes.

Negative effects of habitat degradation can, in some cases, be mitigated through translocation, a wildlife management technique where animals are moved from one location to another, with threats usually having been ameliorated at the release location

(Germano and Bishop 2009; DeGregorio *et al.* 2020; Poor *et al.* 2020). Although reptiles are historically underrepresented in translocation studies, the global decline of reptile biodiversity necessitates novel translocation strategies to protect populations from the negative impacts of urbanisation (Gibbons *et al.* 2000; Tuberville *et al.* 2005; Germano and Bishop 2009). Previous studies have produced mixed success in translocation of reptiles. Hard-release translocation, the most common approach, consists of moving animals immediately from their capture location to their translocation site. However, hard-release translocations can leave animals in a disoriented state that often results in high mortality rates due to long movements or homing attempts (Germano and Bishop 2009; DeGregorio *et al.* 2020; Bilby and Moseby 2024). Soft-release translocation is an alternative approach that attempts to reduce erratic movements and homing attempts by providing an acclimation period in an enclosure at the site of translocation before releasing the animals. In some studies, soft-release has been found to decrease post-translocation movements and homing attempts, thus promoting new home range establishment (Tuberville *et al.* 2005; Tetzlaff *et al.* 2019; DeGregorio *et al.* 2020). A study on the soft-release of Texas horned lizards (*Phrynosoma cornutum*) demonstrated that juvenile lizards responded well to soft-release translocations, but adult lizards experienced an unsustainably high mortality rate (DeGregorio *et al.* 2020). Another study compared hard-release and soft-release translocation treatments in an attempt to re-establish a population of gopher tortoises (*Gopherus polyphemus*), finding that soft-release, as well as increasing duration of time spent in the soft-release enclosure, greatly increased tortoise site fidelity and drastically reduced the number of attempted individual dispersal events relative to the hard-released tortoises (Tuberville *et al.* 2005). Positive responses to soft-release translocation by gopher tortoises (Tuberville *et al.* 2005) and juvenile Texas horned lizards (DeGregorio *et al.* 2020) not only highlight the importance of using an alternate translocation strategy to mitigate negative effects of hard-release, but also emphasise the necessity of the further development of novel translocation strategies to promote new home range establishment.

The common box turtle (*Terrapene carolina*) is one of 360 turtle species currently listed as threatened with extinction (van Dijk 2011; Greenspan *et al.* 2015; Stanford *et al.* 2020). The home range size of *T. carolina* can vary geographically and with habitat type, but is generally between 1 and 5 ha. Individuals are non-territorial and have overlapping home ranges, with populations often at relatively high densities (Ernst and Lovich 2009; Greenspan *et al.* 2015; West and Klukowski 2016). *T. carolina* exhibits a slow life history, characterised by low recruitment rates, slow maturation and high adult survivorship with negligible reproductive senescence (Miller 2001; Dodd 2002; Henriquez *et al.* 2017), which renders populations vulnerable to the effects of habitat loss and degradation due to their inability to quickly rebound from declines in adult survivorship (Budischak *et al.* 2006; Henriquez *et al.* 2017; Stanford *et al.* 2020). Populations subject to forest urbanisation have the ability to persist in residential neighbourhoods and green spaces within urban areas that maintain critical habitat elements (Budischak *et al.* 2006; Brisbin *et al.* 2008; Fredericksen 2014). However, modern construction practices are often unsustainable for box turtle populations because mortality of turtles is likely with complete clearing of land and extensive mechanical landscape. Consequently, box turtles are commonly managed with translocation. Hard-release translocations of adult box turtles often fail due to their strong home range fidelity and resistance towards new home range establishment (Refsnider *et al.* 2012; Harris *et al.* 2020; Poor *et al.* 2020). An *ad hoc* translocation study monitored 10 box turtles for about 3 years after a hard-release translocation. Only four turtles established new home ranges, and six had to be repositioned multiple times to keep them within the translocation site (Poor *et al.* 2020). Another study comparing movements and home range sizes between resident and hard-released box turtles found that the hard-released turtles moved farther between relocations, with a more directed orientation in movements than resident turtles, and had increased home range sizes (Rittenhouse *et al.* 2007). A long-distance (approximately 70 km) translocation study of both hard- and soft-released box turtles by Cook (2004) yielded no significant difference in homing attempts between the hard- and soft-released turtles; however, the overall home range establishment rate was low (<50%).

The failure of most box turtles to establish home ranges post-translocation highlights the need for novel translocation strategies (Tuberville *et al.* 2005; DeGregorio *et al.* 2020). In circumstances where translocation recipient sites are temporarily unavailable or homing attempts would lead turtles into direct contact with disturbance, strategies that utilise off-site holding could replicate successful aspects of soft-release techniques while protecting turtles from ongoing construction activities. Thus, the objective of this study was to evaluate long-term, off-site holding as a variation of soft-release translocation for short-distance (~1 km) translocation of three-toed box turtles (*Terrapene carolina triunguis*). We radiotracked 18 translocated box turtles at a site undergoing residential development in Northwest Arkansas, USA, to assess movement patterns and behaviour. Turtles were split into two treatment groups: immediate-release translocation and translocation after long-term holding (>1 year) at an off-site holding facility nearby. We hypothesised that immediate-release turtles would have a stronger tendency to return to their initial capture locations than turtles held long-term before release, as indicated by distance moved and orientation of movements. Specifically, we predicted that turtles in the immediate-release group would average longer daily distances travelled than turtles in the long-term holding group, in efforts to return to their initial capture site. Thus, immediate-release turtles would need to be repositioned back to the original release point at a higher frequency. We also predicted that the immediate-release turtles would exhibit non-random orientation in movement directionality back towards their initial capture locations, whereas turtles in the long-term holding group would exhibit random orientation in movement directionality due to having decreased familiarity with their home landscape after being off-site for over 1 year.

Materials and methods

Study site

Our study site was a predominantly forested region subject to encroaching urbanisation in Fayetteville, Arkansas, USA (Fig. 1). It is densely wooded, with an overstorey composed mostly of ash (*Fraxinus* spp.), cedar (*Cedrus* spp.). elm (*Ulmus* spp.), hickory (*Carya* spp.), and oak (*Quercus* spp.). Invasive bush honeysuckle (*Lonicera* spp.) is prevalent in the midstorey, with removal efforts underway. Vegetation and other refugia such as leaf litter, tree limbs, and fallen trees compose the understorey. Approximately 14 ha of land on the eastern side of the property is experiencing extensive alteration from ongoing residential development, which, in addition to plans for future development on the eastern side of the study site, necessitated translocation of resident box turtles. The western side of the study site is still largely intact forest, of which approximately 30 ha has been set aside as conservation land, and is therefore an ideal site to ensure translocated box turtles remain within their source population. The conservation land is bordered by a four-lane interstate highway to the west, undeveloped private property to the north and residential development areas to the east and south. In addition to the four lanes of heavily trafficked interstate, two side roads run parallel to the interstate, amounting to six lanes of road that a box turtle would have little chance of successfully crossing.

The initial release point (Fig. 1) was located on a densely wooded hillside by an ephemeral stream that was dry throughout the study period. There was minimal midstorey, and herbaceous ground-level vegetation was sparse. Leaf

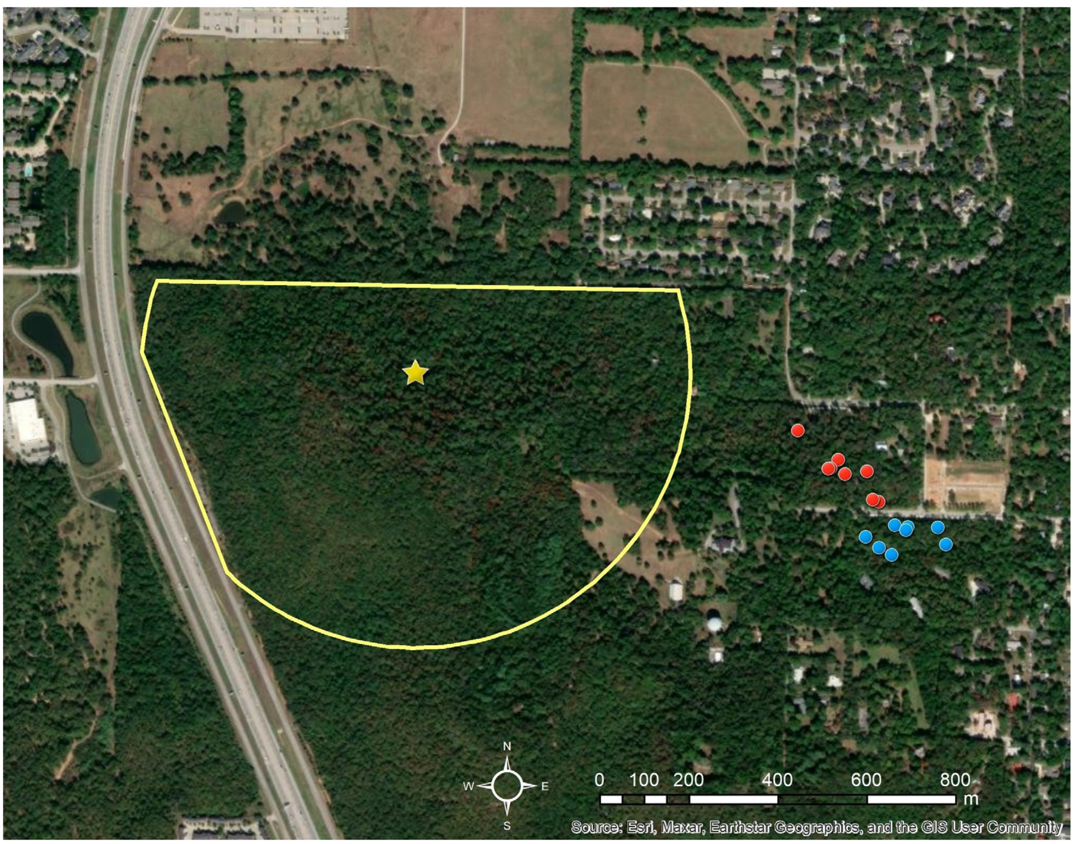

Fig. 1. Map of the study site located in Northwest Arkansas, USA. The red and blue points on the eastern edge of the property represent the initial capture (home) locations of the immediate-release and long-term holding three-toed box turtles (*Terrapene carolina triunguis*), respectively. The yellow star denotes the initial release point of the box turtles in the translocation site. The perimeter of the translocation site, delineated in yellow, was established by a 500-m radius from the release point, a private property line to the north and a highway to the west. Box turtles that moved past the perimeter were repositioned to the release point.

litter and fallen trees were prevalent and often used by the turtles for refugia. The release point was 750–1000 m from the initial capture locations of turtles in both treatments and similar to their initial capture site and the long-term holding site in habitat structure. We established a translocation site of approximately 53 ha around the release point to maintain the translocated turtles. Box turtles have relatively small average home ranges, estimated at 2.04 ha, for this Ozark/Ouachita–Appalachian forest ecoregion (Habeck *et al.* 2019), thus the translocation site allowed ample space for movement and home range establishment.

To establish the translocation site, we delineated a perimeter around the initial release point to guide repositioning decisions (Fig. 1). This perimeter included a private property line to the north, a slight buffer from the highway to the west and a 500-m radius from the initial release point for the rest of the translocation site area. Turtles that moved past the perimeter were moved back to the initial release point. Thus, the perimeter prevented movements of the turtles back to the construction zone, into the road or into private property where they could face other dangers, such as mowing, and might not be able to be tracked. Hereafter we will refer to individual tracking locations of box turtles as 'relocations,' and the event of moving turtles that crossed the translocation site boundary back to the initial release point as 'repositioning.'

Establishment of treatments

Box turtles used in this study were divided into two treatment groups: immediate-release translocation and long-term holding prior to translocation. Each treatment had a sample size of nine box turtles, with as close to a 1:1 sex ratio as possible. We recorded the initial mass of each turtle prior to translocation and their final mass at the end of the study. Each turtle was given a unique identification code by filing a set of notches in the marginal scutes (Cagle 1939). We affixed a 15-g radio transmitter (Holohil Systems Inc., Model RI-2B) with JB Weld Waterweld Epoxy to the left anterior carapace of each turtle so as not to impede mating (Boarman *et al.* 1998). The weight of the transmitters was no more than 5% of the total body mass of each turtle.

The long-term holding treatment initially consisted of eight (4F, 4M) turtles that had been collected from an area of future residential development at the study site between 16 August and 11 November 2020, and held at a private off-site holding facility for 18 to 21 months prior to release. The holding facility consisted of a 2 m × 3 m outdoor pen under partial canopy cover in forest ~2 km from the study site. These turtles were housed communally, provided water *ad. libitum* and fed a mixture of vegetable scraps, greens and seasonal natural foods (mushrooms, persimmons, mulberries, etc.) several times per week between April and October. For the immediate-release treatment, we initially collected eight (4F, 4M) turtles between 26 and 30 April 2022, directly from the same area of future residential development and translocated them immediately after processing (<2 weeks after capture).

One male turtle from the long-term holding treatment group died from a natural injury, presumably inflicted by a predator, after a tracking period of 31 days. We replaced this turtle with another male from the off-site holding facility and added a female turtle to the immediate-release group to maintain a balanced sample size. Both new turtles were translocated on 16 June 2022 and tracked for the remaining 45 days of the study. Thus, the final sample size of each treatment group was nine box turtles (5F, 4M immediate-release; 4F, 5M long-term holding). No additional, non-radiotracked turtles were translocated during this study.

Radiotelemetry and data collection

Following release, we used a handheld telemetry receiver (Communications Specialists, Inc., Model R-1000) to track the translocated box turtles for a maximum of 83 days (9 May–31 July 2022) and record their locations. We tracked the turtles daily (weather permitting) from 9 May to 24 June. Turtle activity slowed in mid-summer, so for the remainder of the study (24 June–31 July), we tracked the turtles every 2–3 days. For each GPS coordinate taken, we noted turtle behaviour (inactive, active, mating, eating/drinking). When a turtle was in motion upon relocation, we defined its behaviour as active. Inactive behaviour included basking, resting and hiding under leaf litter or refugia.

Statistical analysis

We performed all statistical analyses using packages in program R ver. 4.3.1 (R Core Team 2021). We compared the mean number of reposition events required per turtle and the latency of the first repositioning event among treatment groups using Student's *t*-tests. Despite the addition of one turtle to each group halfway through the study, we did not include time in reposition calculations because the total tracking duration was balanced across treatments. We used the 'adehabitatLT' package (Calenge 2006) to analyse movement paths and calculate the mean linear distance moved per day for each turtle. Because the sex ratio of the nine turtles in each treatment group was close to 1:1, we analysed differences in distance moved per day between the sexes using the Student's *t*-test. There was no statistically significant difference between the sexes in daily movement distances, so sex was not included as a predictor variable in subsequent statistical analyses.

To determine if the turtles in each treatment group exhibited directional movement towards their initial capture (home) location, we performed the Rayleigh test of uniformity using the 'CircStats' package (Landler *et al.* 2018; Lund and Agostinelli 2022). For each turtle's final location at the end of the study or when it moved outside of the boundary and needed to be repositioned, we calculated the bearing between the initial release point and the final point using 'adehabitatLT' (Calenge 2006). We then corrected this bearing by subtracting it from the bearing between the initial release point and the turtle's initial (home) capture location, such that movement directly towards a turtle's 'home' location would have a bearing of 0°. For turtles that were repositioned multiple times, we took the circular mean bearing of their repositions, yielding one mean bearing per turtle, and plotted the bearings on a circle plot for each treatment group using the 'circular' package (Lund and Agostinelli 2022). The Rayleigh test gave two results for each treatment group to describe the distribution of their respective bearings plotted on a circle: an $\bar{R}$ value and a *P*-value. The $\bar{R}$ value describes the distribution of points around a circle, where $\bar{R} = 0$ represents data that are evenly distributed around a circle, and $\bar{R} = 1$ represents data that are all oriented along the same bearing. For each treatment group, a significant *P*-value ($\alpha < 0.05$) indicated that the data were directionally oriented towards a specific point, whereas a non-significant *P*-value indicated that the data were not different from a random distribution of bearings. We calculated the circular variance of reposition bearings for each turtle using 'circular,' then took the mean circular variance of both treatment groups (Lund and Agostinelli 2022).

We compared behavioural differences between the treatment groups by graphing the proportions of observed behaviours relative to the total number of relocations for each respective group. We determined the change in mass experienced by each turtle over the course of the study by calculating the difference in mass (final minus initial mass) and dividing it by the final mass of each turtle, yielding the percentage change over the study period. We conducted a Student's *t*-test to compare mass changes between treatment groups. Means are presented ±1 standard error and significance was recognised at $\alpha < 0.05$ for all analyses in this study.

Results

Throughout the 83-day tracking period of the study, we made a total of 716 relocations of the 18 turtles: 370 relocations of the immediate-release turtles and 346 relocations of the long-term holding turtles. Turtles in the immediate-release treatment needed to be repositioned back to the initial release point 92% more frequently (mean = 11.9 ± 3.2 repositions per turtle) than turtles in the long-term holding group (mean = 6.2 ± 1.9 repositions per turtle) to keep them within the designated area (Figs 1 and 2); however, this difference was not statistically significant (Student's *t*-test; $t_{d.f. = 8} = 1.270$; $P = 0.240$). Turtles in the long-term holding group had a latency to the first repositioning event that was more than twice (mean = 14.9 ± 2.8 days) the latency of turtles in the immediate-release group (mean = 6.6 ± 2.8 days); however, this difference was not statistically significant (Student's *t*-test; $t_{d.f. = 8} = -0.906$; $P = 0.391$). The immediate-release turtles moved nearly twice as far per day (mean = 178 ± 18 m) as turtles in the long-term holding group (mean = 99 ± 12 m; Fig. 3); this difference was statistically significant (Student's *t*-test; $t_{d.f. = 8} = 3.393$; $P = 0.009$). Males (mean = 134 ± 21 m) and females (mean = 143 ± 20 m) did not differ (Student's *t*-test; $t_{d.f. = 8} = -0.391$; $P = 0.706$) in mean linear distance moved per day (Fig. 3).

Examination of movement bearings using the Rayleigh test demonstrated marked differences in movement of turtles between the treatment groups (Fig. 4). Turtles in the immediate-release treatment group exhibited directional movements towards their initial capture (home) coordinates, with circular mean bearings of each turtle near 0° ($\bar{R} = 0.903$; $P < 0.001$). The movements of turtles in the long-term holding group were not directional ($\bar{R} = 0.162$; $P = 0.799$) and were widely distributed relative to their initial capture (home) coordinates. Turtles in the long-term holding group had a larger mean circular variance (mean = 0.285 rad^2) about their mean circular bearings than turtles in the immediate-release treatment group (mean = 0.096 rad^2).

Box turtles in both groups exhibited very similar proportions of behaviours relative to their respective number of relocations (Fig. 5). The most frequently observed behaviour was inactive for both treatment groups, accounting for about 72% of immediate-release and 70% of long-term holding relocations. Roughly 30% of observed behaviour in the remaining relocations for both groups consisted of active, mating and eating/drinking. Throughout this study, we observed box turtles eating berries, fungi and earthworms, and scavenging a mole (*Scalopus aquaticus*) carcass.

Box turtles in both the immediate-release (mean percentage difference per final mass = −1.4 ± 1.1%) and long-term holding groups (mean percentage difference per final mass = −2.4 ± 1.0%) lost mass; however, differences between the groups were not significant (Student's *t*-test; $t_{d.f. = 7} = 0.600$; $P = 0.567$).

Discussion

In this study, long-term holding of *T. c. triunguis* prior to translocation had a biologically significant influence on movements in comparison with immediate-release turtles. Though the individuals in both groups experienced a short-distance translocation relative to their initial capture locations, only the immediate-release turtles made consistent homing attempts. The non-directional movements of turtles subjected to long-term holding indicate that holding box turtles off-site prior to translocation helped mitigate the issue of homing frequently observed in immediate-release turtles. Turtles held long-term also had significantly shorter linear mean daily distances moved than immediate-release turtles, required less frequent repositioning and had a longer latency to the

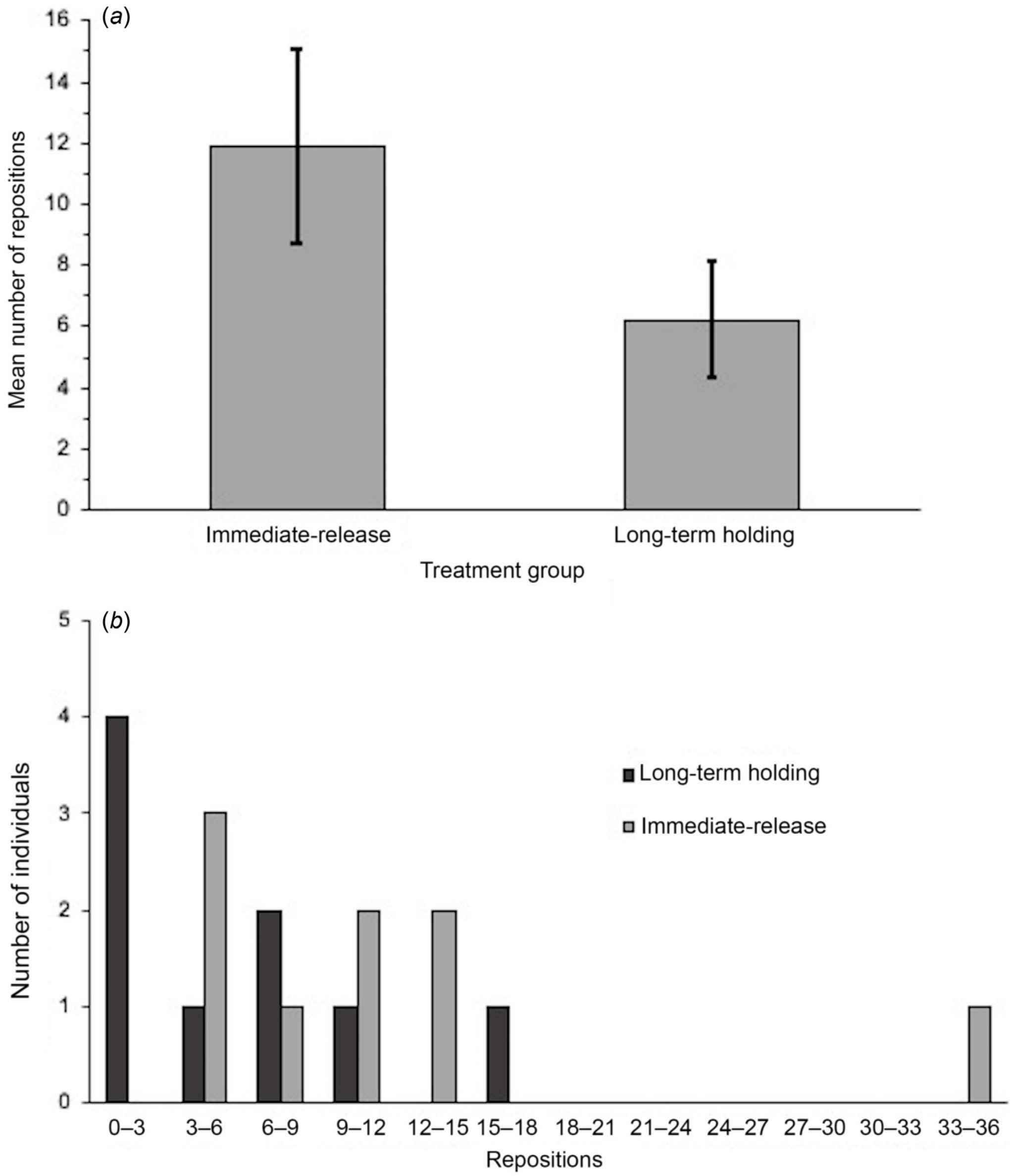

Fig. 2. (*a*) Mean and (*b*) frequency distribution of the number of repositions required to keep immediate-release (Mean = 11.9 ± 3.2 repositions) and long-term holding (Mean = 6.2 ± 1.9 repositions) translocated *Terrapene carolina triunguis* within the designated translocation site (Fig. 1) in Fayetteville, Arkansas, USA. Immediate-release turtles required a higher frequency of repositions, but the difference between the groups was not statistically significant (Student's *t*-test; $t_{d.f. = 8} = 1.270$; $P = 0.240$). Error bars represent ±1 standard error of the mean.

first repositioning event. Thus, box turtles held long-term before translocation could be more likely to establish new home ranges than turtles translocated immediately upon capture.

The high site fidelity of immediate-release turtles to their original capture locations and resistance toward establishment of new home ranges observed in this study was consistent with previous hard-release translocation studies of box turtles (Rittenhouse *et al*. 2007; Refsnider *et al*. 2012; Harris *et al*. 2020; Poor *et al*. 2020). Only one turtle in the immediate-release group did not repeatedly move back towards its original capture location. Yet, this individual did still exhibit extremely unidirectional movements and needed to be repositioned 36 times throughout the study, more frequently than any other turtle. Poor *et al.* (2020) suggested that the post-translocation repositioning of individuals could promote home range establishment, yet just one immediate-release turtle consistently remained within the translocation site by the end of the study. Without consistent repositioning, the rest of the immediate-release box turtles would have returned to their

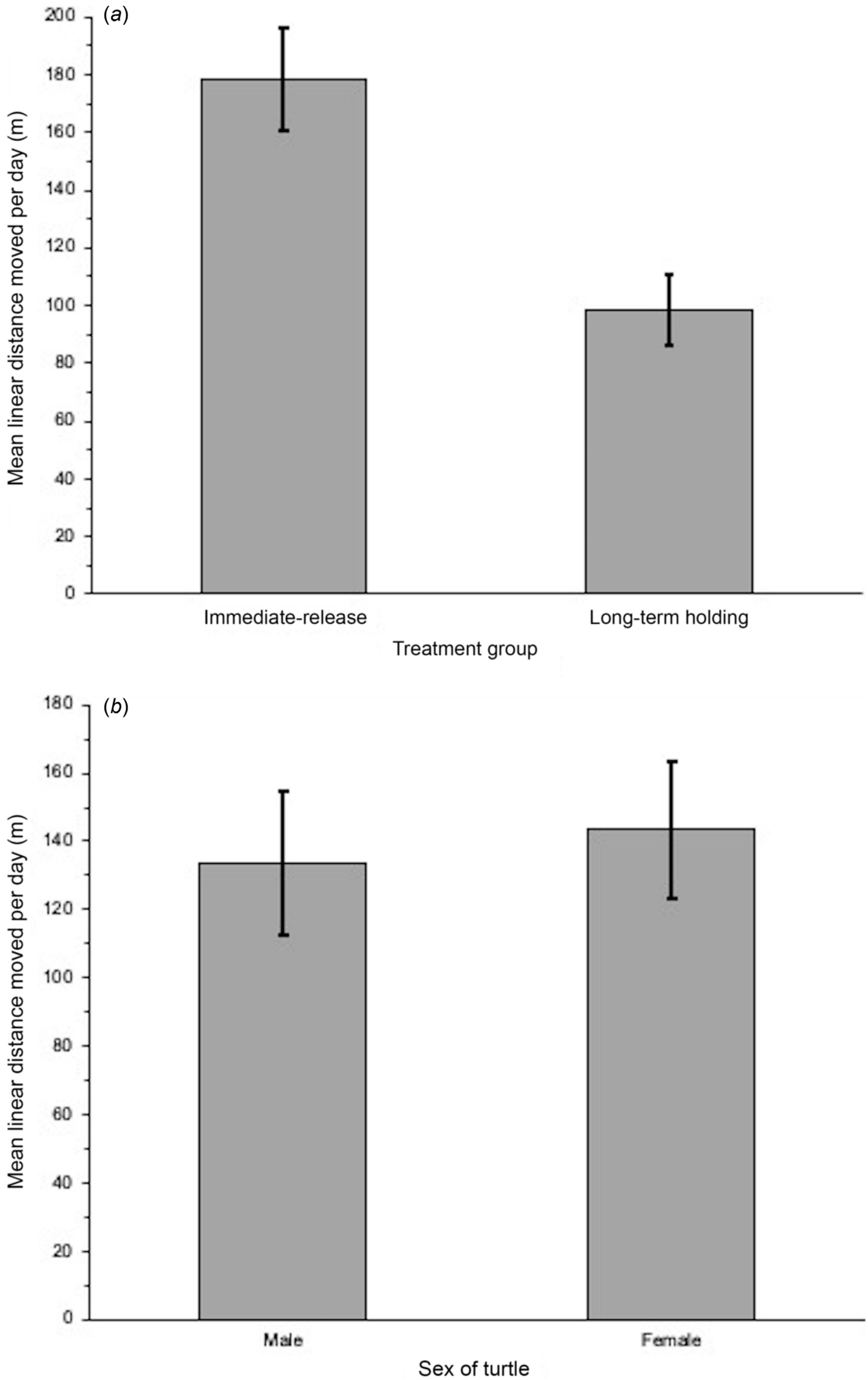

Fig. 3. Mean linear distance moved per day (m) by translocated *Terrapene carolina triunguis* in Fayetteville, Arkansas, USA, (*a*) by treatment group and (*b*) by sex. The difference between immediate-release (178 ± 18 m) and long-term holding (99 ± 12 m) treatment groups was statistically significant (Student's *t*-test; $t_{d.f. = 8} = 3.393$; $P = 0.009$). Males (134 ± 21 m) and females (144 ± 20 m) did not differ significantly (Student's *t*-test; $t_{d.f. = 8} = -0.391$; $P = 0.706$) in mean linear distance moved per day. Error bars represent ±1 standard error of the mean.

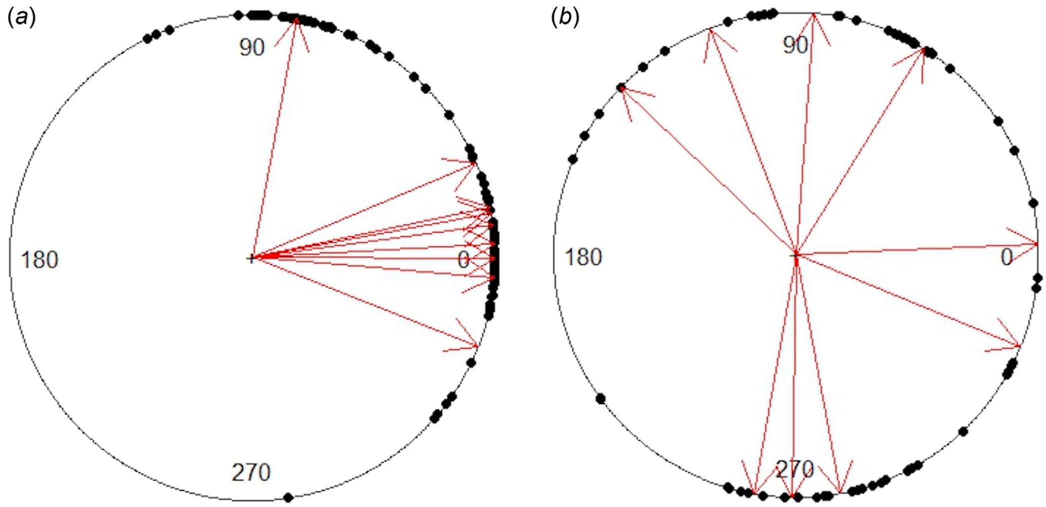

Fig. 4. Movement bearings of translocated *Terrapene carolina triunguis* subjected to immediate-release and long-term holding, within the study site (Fig. 1) in Fayetteville, Arkansas, USA. Black points indicate bearings of the individual repositioning events for all turtles in both groups. Red arrows represent the circular mean bearing of repositioning for each individual box turtle in each group. The bearings were corrected for each turtle such that their initial capture (home) location would have a bearing of 0°. The immediate-release group, shown in plot (*a*), exhibited extremely directional movements towards their home locations (Rayleigh test: $\bar{R} = 0.903$; $P < 0.001$), as indicated by the concentration of points and red arrows near 0°. Movement bearings of turtles in the long-term holding group, shown in plot (*b*), did not differ significantly from random (Rayleigh test: $\bar{R} = 0.162$; $P = 0.799$), as indicated by the even distribution of points and arrows around the plot.

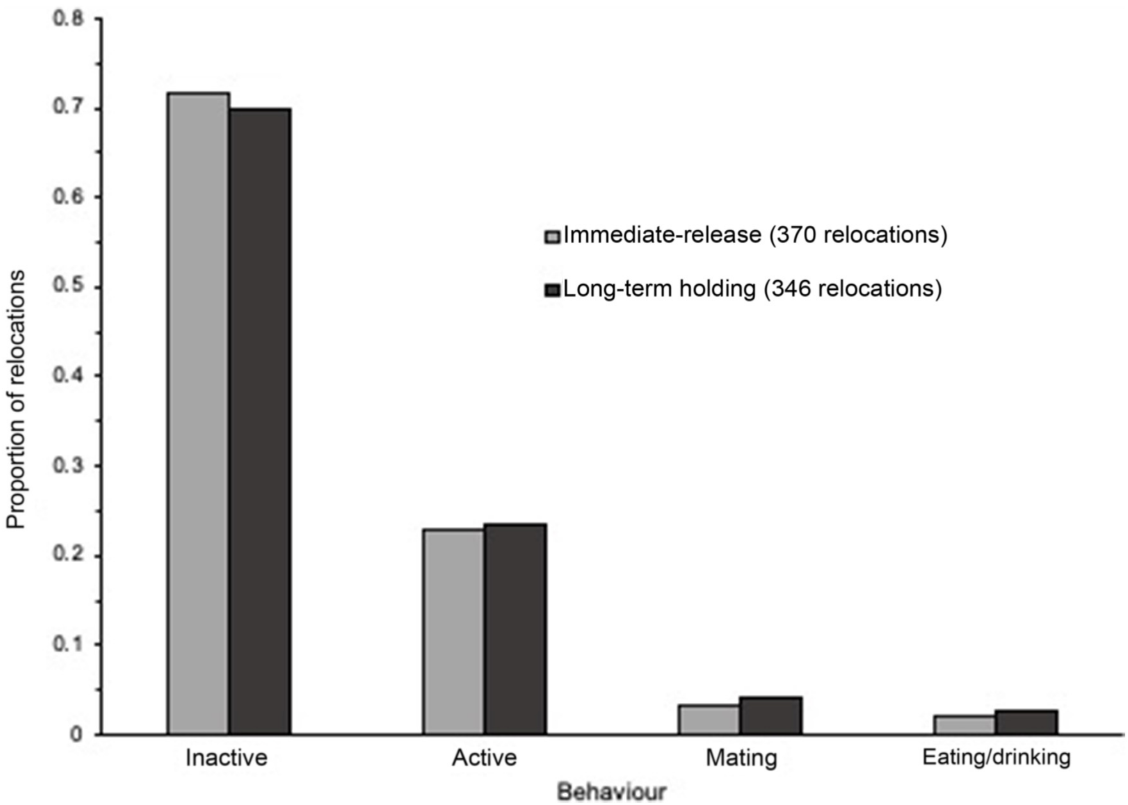

Fig. 5. Behaviour exhibited by immediate-release and long-term holding *Terrapene carolina triunguis* translocated in Fayetteville, Arkansas, USA, relative to their respective number of relocations.

home areas where they would be at risk from construction activities. Similar to observations by Poor *et al*. (2020), immediate-release translocation of box turtles a short distance from their original site of capture does not seem to be a practical management strategy.

The present study indicates that collection of box turtles from a developing landscape to hold off-site not only prevents mortality of turtles during construction activities but also mitigates homing tendencies observed in hard-released turtles when translocated a short distance from their initial capture locations. One long-term holding turtle remained within the translocation site for the entirety of the tracking period and did not require repositioning. Four of the long-term holding turtles did not require repositioning for the final 4–5 weeks of the study, and all long-term holding turtles (with exception of the individual that died of injuries) remained within the translocation site for ≥20 days without repositioning by the end of the study. However, it is still unclear whether these turtles successfully established new home ranges. Many studies emphasise the need to monitor translocated box turtles for several years to determine if site fidelity exhibited after translocation is temporary or reflects establishment of a true home range. Additionally, empirical studies of box turtle home ranges have yielded variable results due to variation in home range metrics and analytical methods used, habitat variation or individual turtle differences, further complicating our ability to classify home range establishment by comparison with the literature (Cook 2004; Rittenhouse *et al*. 2007; Refsnider *et al*. 2012; Habeck *et al*. 2019).

Reduced homing attempts we observed in the long-term holding treatment of this study were similar to those observed in soft-released gopher tortoises (Tuberville *et al*. 2005). Box turtles are known to use their familiarity with physical landmarks and sun-compass orientation for navigation and homing (Dodd 2002). Therefore, it is possible that long-term holding before short-distance translocation and soft-release similarly influence the homing tendency of turtles after translocation by affecting their familiarity with the landscape to which they were translocated. Holding box turtles at an off-site location for approximately 1.5 years in this study may have weakened turtles' ability to recognise familiar landmarks from their initial capture locations compared with the immediate-release turtles that moved consistently back towards their capture locations. Soft-release of gopher tortoises into pens in Tuberville *et al*. (2005) would have increased their landmark familiarity within and around the pens, perhaps playing a key role in discouraging the tortoises from homing. The long-distance translocation in Cook (2004) would have similarly functioned to eliminate homing via landmark familiarity; however, the lack of home range establishment in both the hard- and soft-released turtles indicates translocation of turtles to a novel environment is not an effective method of translocation. Although Cook (2004) investigated translocation of 'captive' turtles held off-site before release, the variability of time in which individuals were held off-site makes it unclear what effect time spent in captivity really had on movements of translocated turtles. Individuals that successfully established a home range within the site were significantly oriented in a homeward direction, but turtles that dispersed from the site did not exhibit a significant orientation or homing attempt (Cook 2004).

Success of translocation can, in part, be evaluated by changes in mass of the box turtles over the course of the study, where a significantly different change in mass between treatment groups could indicate differences in stress levels induced by different translocation methods. Though most turtles experienced a minor decrease in body mass by the end of this study, nesting and water loss during drought conditions (~2 months with negligible precipitation during this study) were suspected to be the main contributors. Seasonal variation in body condition is commonly observed in box turtles, likely a result of mate-searching and nesting in males and females, respectively (Budischak *et al*. 2006). Furthermore, mass loss did not differ significantly between the treatment groups, indicating similar levels of stress across treatments.

Long-term holding of box turtles at an off-site location seems to be a promising strategy for mitigating homing attempts of box turtles in short-distance translocations and protecting turtle populations from construction or land-restoration activities. Long-term holding before translocation back to a site near the initial capture location did not present the disadvantage of having to move the turtles to an unfamiliar habitat a long distance from their capture locations, as performed by Cook (2004). Short-distance translocation also allows turtles to remain within their source population, thus supporting population persistence and genetic diversity, rather than just survival of individuals. Additionally, long-term holding of turtles at existing wildlife facilities is inexpensive and less time-intensive than construction and maintenance of a soft-release enclosure. Long-term holding would also be ideal if the designated translocation site is undergoing intense restoration management, preventing immediate soft-release translocation. However, further investigation of long-term holding as a translocation strategy is necessary. Box turtles should be tracked for at least 1 year after translocation to investigate if site fidelity exhibited by box turtles is temporary or if the turtles have actually established novel home ranges. Continuing to track the translocated turtles would also allow long-term changes in survival to be monitored. Tracking resident box turtles within the translocation site to determine home range size would provide a useful standard to compare home ranges of the varying treatments of translocated turtles, as well as monitor any differences in long-term survival exhibited between groups. Long-term holding and soft-release (penning within the translocation site prior to release) translocation methods should be compared directly through both short- and long-distance translocation studies to elucidate the most effective method of translocation in various contexts.

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Data availability. The data that support this study will be shared upon reasonable request to the corresponding author.

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