

Research article

Homing of translocated native Indian pythons in Moyar River Valley, South India

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ABSTRACT

Homing is often a critical aspect of an animal's behavioural and spatial ecology. Translocation is considered to be a wildlife management strategy that could reduce human-wildlife confrontation, but this strategy may not be effective if animals attempt to home to their original capture location. Translocation of animals from sites where possible human-wildlife interaction occurs is a widespread but controversial intervention to resolve conflicts. In India, snakes are often the subject of such translocations, but there is a paucity of information on the behaviour of translocated snakes compared to resident snakes. The Indian python (*Python molurus*), one of the largest carnivores in the Indian subcontinent, is classified as Near Threatened by the IUCN. We conducted a two-year radio-tracking study (December 2018 to December 2020) on the movements of 14 adult Indian pythons in the Moyar River Valley, within the Sathyamangalam and Mudumalai Tiger Reserves. Eleven of the 14 pythons were translocated 0.28–55.7 kms from their capture locations, while 3 pythons were not translocated: 6 were translocated short distances (<5 km from capture; range 0.28–4.67 kms), 2 were translocated to medium distances (9–11 kms from capture location), and 3 were translocated to long distances (21–55.7 kms from capture location). Four of the six snakes translocated short distances all returned to within 500 m of their original capture locations, and all 6 returned over 60 % of the translocated distance to the initial capture location. Of the two snakes translocated medium distances, both returned to within 1.1 km of the capture location (~90 % of the distance home). None of the three snakes that were translocated long distances successfully returned to their capture locations. Translocated pythons exhibited greater net movement distances than resident snakes within the first 2 months of release. Based on these results, long-distance translocation may be an effective strategy to minimize human-python conflict, while short or medium distance translocation is unlikely to be successful. However, more research is needed about the long-term survival of translocated snakes as well as soft-release methodologies that could prevent aberrant movement behaviour directly following release.

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1. Introduction

The practice of moving animals for conservation or wildlife management purposes is increasing [1]. Animals may be removed from an area due to serious threats to their survival [2,3], conflict mitigation [4,5], to aid colonization in response to climate change [6], to increase genetic variation [7], and for the re-establishment of extirpated populations [8,9]. Many of these translocation efforts are a component of general conservation practices and the re-establishment of animal populations. The homing capacity of snakes has not been studied extensively [10], however there is evidence that some snakes are capable of homing after being translocated [10,11].

Translocating snakes is a common practice for managing human–snake conflict and is used for the conservation and management of wildlife [12,13]. However, translocation efforts are sometimes not successful because of the navigational capacity of the species. A study reported that invasive Burmese pythons (*Python bivittatus*) translocated distances of 21–36 km in South Florida could return home [10]. However, other studies have reported successful translocations in which snakes did not navigate home [14,15]. A study on the white-lipped pit vipers (*Trimeresurus albolabris*) in China showed snakes translocated greater than 3 kms were not able to navigate home; however, snakes displayed unidirectional movement not associated with the establishment of a new home range [16].

Reintroduction attempts often fail to result in the establishment of viable populations for numerous reasons [14,17]. Translocations cause unintended consequences to the animal, including behavioral changes, reproductive dysfunctions [18], predator naivety [19], and the inability to locate suitable food or shelter [20]. The low success of reintroduction programs has led to the advancement of many novel techniques that seek to improve the survival and reproduction of translocated individuals. Previous studies suggest several crucial improvements for wildlife relocations, including the need for more rigorous testing to assess the appropriateness of the approach, the establishment of criteria to evaluate relocation a success or failure, comprehensive post-relocation monitoring, financial accountability to ensure responsible resource allocation, and increased transparency in publishing results [17,21]. In the realm of habitat restoration, a study reports four pivotal elements: identifying and securing suitable areas, restoring indigenous vegetation before translocation, and implementing long-term habitat management to prevent elevated mortality or dispersal [22]. Indian Pythons (*Python molurus*) are facing severe threats from anthropogenic activities, habitat degradation, and habitat loss, and are currently listed as Near Threatened by the IUCN [23]. Further, this species is safeguarded under the Schedule-I of the Indian Wildlife (Protection) Act – 1972 and is included in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora. Therefore, minimizing human-wildlife conflict while maximizing the survival of this species is the central goal of conservation efforts. Limited information is available on the movement patterns and navigational abilities of Indian rock pythons. However, the average AKDE (Auto correlated Kernel Density Estimates) home range size of *P. molurus* has been reported as 4.2 km², and the *P. molurus* is

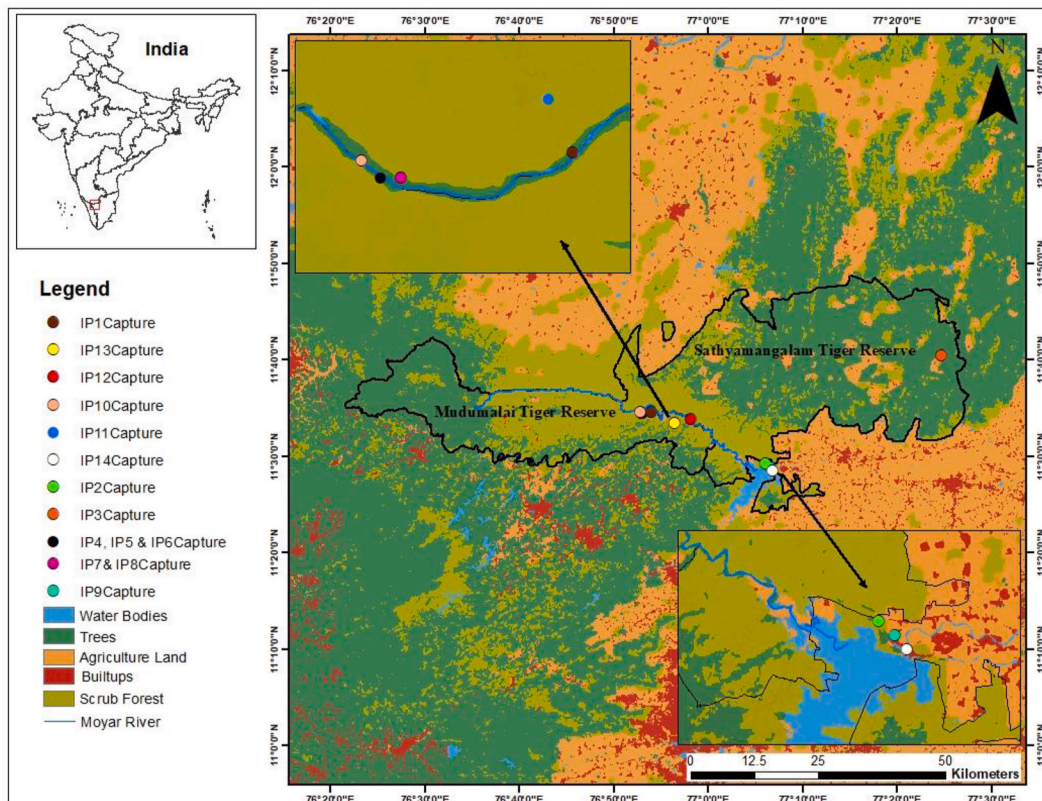


Fig. 1. Initial capture locations of Indian rock pythons in and around the Sathyamangalam and Mudumalai Tiger Reserves.

known to have larger home ranges compared to other python species reported to date [24].

Previous research on the closely related Burmese python in both its invasive and native ranges have suggested that the Indian python may be capable of long-distance movement. The Minimum Convex Polygon (MCP) home range size of the Burmese python (*P. bivittatus*) in its native range was reported to be 12.3 ha over a period of 24 days [25]. Similarly, a study [26] observed that Burmese pythons in their native range moved an average of 41.56 ± 7.43 m per day, as determined by dynamic Brownian Bridge Movement Models.

To understand the homing capacity of native Indian pythons, we used radiotelemetry to study their movements and activity patterns in the Moyar River Valley, Southern India, during 2018–2020. We tracked 14 individuals and translocated 11 of them to distances ranging from 200 m to 50 km from their original capture locations (Fig. 1). This study reports and discusses the movement and homing capabilities of these translocated pythons.

To understand the homing capacity of native Indian pythons, we used radiotelemetry during 2018–2020 to study the movements and activity patterns of pythons in Moyar River Valley, Southern India. As part of that study, we radio-tracked 14 individuals, and translocated 11 of those individuals 200 m–50 kms from their original capture locations (Fig. 1). Herein, we report and discuss the implications of the movement and homing capabilities of these translocated pythons.

2. Methods

2.1. Study animal

The Indian python (*Python molurus*) is a non-venomous snake known for its ambush foraging behavior and substantial body size. Adult individuals typically measure between six to 8 m on average from snout to vent [27]. Male Indian pythons have been recorded to reach sexual maturity at a minimum snout to vent length of 172 cm [28]. The Indian python is widely distributed in the Indian subcontinent [23,29–31]. They occupy a diverse array of habitats, including dry lands, wetlands, forests, and tropical rainforests [32]. Furthermore, their climbing abilities label them as semi-arboreal, while they hunt a diverse array of birds, small to medium-sized mammals, and reptiles [33].

2.2. Study area

The Moyar River courses through the regions of Sathyamangalam and Mudumalai Tiger Reserves, contributing its waters to the Bhavani Sagar Reservoir in Tamil Nadu, South India. This locale forms part of the Nilgiri Biosphere Reserve-Sigur plateau, situated at the confluence of the Western and Eastern Ghats [34], and hosts a diverse array of wildlife species [35,36]. The Mudumalai Tiger Reserve (MTR) is nestled within the Western Ghats ($11^{\circ}32' - 11^{\circ}43'N$, $76^{\circ}22' - 76^{\circ}45'E$), renowned for its rich floral and faunal diversity, covering an expanse of 588.59 km² [34]. Dominant forest types in the area include Southern tropical dry deciduous, Southern tropical dry thorn, Southern tropical semi-evergreen, Southern tropical moist deciduous, Moist bamboo brakes, and Riparian forests [37].

The Sathyamangalam Tiger Reserve (STR), positioned at the juncture of the Eastern and Western Ghats [38], stands as Tamil Nadu's largest Tiger Reserve ($10^{\circ}29'15''$ to $11^{\circ}43'11''N$ and $76^{\circ}50'46''$ to $77^{\circ}27'22''E$), established in 2013, sprawling across 1400 km² [39]. Elevations in this region range from 250 m to 1450 m above sea level, fostering a tropical dry forest ecosystem that encompasses dry deciduous, dry thorn semi-evergreen, and savanna forests [39].

2.3. Experimental set up and study design

We found pythons by searching for tracks and shed-skins within termite mounds, holes and dense hedge rows near human settlements. We were also able to capture pythons by following the movements of radio-tracked snakes during the mating season which led us to non-tagged conspecifics. We manually captured the pythons, temporarily restrained each one in a snake bag inside a spacious plastic storage container. Three pythons (IP2, IP3, and IP9) were captured from human habitation on agriculture land and one python (IP14) was spotted near a factory premise in a habitat patch that connects to forested land. All other individuals were captured from core forests to test their homing ability with respect to the translocation distance. We measured the weight, snout-to-vent length (SVL), total length (TL), and girth of each python. We additionally took photographs of each python in order to identify each individual using the blotch pattern method [27]. Snakes were anesthetized during implantation surgeries and fitted with AI-2 Holohill VHF transmitters (17 g, 24 months, 38×15 mm and 28 g, 36 months, 46×17 mm) as well as ATS ARChive ARC400 Transmitters (Tag $32 \times 20 \times 15$ mm, 14 gms, 239 days). The implants were placed into the coelomic cavity of pythons [24,40] at the STR Veterinary Unit. Snakes were released within 1 week of original capture. The release locations were planned using Google Earth software, and trail field surveys were conducted at release locations to check availability of water, low proximity to villages and villager activities and cattle, prey availability (observations of prey or their scats), and micro-habitats (rock crevices, bushes, leaf litter, and basking areas). Indian pythons exhibit micro-habitat specificity, with a strong preference for green and dry bushes in the study area [41].

Between December 2018 and December 2020, we conducted radio-tracking of pythons within the Sathyamangalam and Mudumalai Tiger Reserves. Radio-tracking ceased between March 17, 2020, and September 06, 2020, in response to the COVID-19 pandemic. Additionally, tracking of pythons was inconsistent due to various barriers such as less workforce, limited transportation, high elephant presence, and increased water flow in the rivers and streams during the monsoon. The actual mean ($\pm 1SD$) time lag between tracking days was found to be 16 ± 35 days, with a range of 0.2–238 days. The tracking period varied between 44 and 695 days, averaging 444 ± 212 days. During this timeframe, each individual yielded an average of 29 ± 16 data points, with the range

varying from 8 to 65.

Eleven of the 14 pythons were translocated 0.2–55.7 kms from their capture locations, while 2 pythons were not translocated. IP12 was translocated 200 m away from the capture location. However, this individual was found very close to the release site within a few hours. Therefore, we treat IP12 as a resident for the purpose of our movement and homing analysis. Six snakes were translocated short distances (<5 kms from capture location; range 0.28–4.67 kms), 2 were translocated medium distances (9–11 kms from capture location), and 3 were translocated long distances (21–55.7 kms from capture location; Fig. 1). All pythons were released in habitat suitable for python habitation (determined by the presence of other pythons in the area). Using a handheld GPS device, a Yagi-type antenna, and an ATS receiver, we collected the locations of pythons on each tracking day [24].

We measured the Euclidean distance between each successive relocation and the distance between each successive relocation and the original capture location. We calculated mean daily movement for translocated and resident pythons within 60 days of release or until the python moved to within 1000 m of the capture location (whichever occurred first). Daily movement was calculated by dividing the straight-line distance between successive relocations by the number of days between relocations. Within the first 60 days post-release, pythons were tracked on average once per week, and sometimes more or less frequently. To determine whether translocated snakes moved more than resident snakes, we used a box plot (Fig. 2) to compare maximum net distance moved between resident and translocated snakes within 60 days post-release. Maximum net distance moved was calculated by determining the maximum Euclidean distance that a snake moved away from the release location within 60 days post-release.

We determined that a python had successfully ‘homed’ if the python moved at least 60 % of the translocation distance back to the original capture location.

2.4. Approval for animal use

The research received ethical approval with permission from the Ministry of Environment, Forests and Climate Change (MoEF), as well as the Tamil Nadu State Forest Department (File No: WL5 (A)/17699/2017; Permit No. 82/2017). Prior to surgery, all pythons were administered gaseous anesthesia with isoflurane. The surgical procedure was conducted by the Chief Veterinarian of the Sathyamangalam Tiger Reserve, according to the specific guidelines outlined in the CPCSEA, Ministry of Environment & Forests, Government of India.

3. Results

3.1. Initial movement behavior

Mean daily movements of resident snakes within the first 60 days of release was 57.0 m (SD = 49.2 m, N = 3). Mean daily movements of translocated snakes was 208 m (SD = 198 m, N = 11). Translocated snakes moved greater net distances from release than resident snakes within the first 60 days post-release (Fig. 2). The closest distance to home was not calculated for the snakes IP8, IP10 and IP14 because radio-tracking was interrupted by the COVID-19 pandemic during the first 60 days post-release (Table .1).

3.2. Evidence of homing

All short and medium distance translocated pythons returned at least 60 % of the way to their original capture location (N = 8) (Fig. 3 & Table .1). Four of these were observed within 400 m of their original capture location. All eight snakes were consistently moved back toward their original capture location for the duration of study (i.e. none were observed to have travelled greater than 20

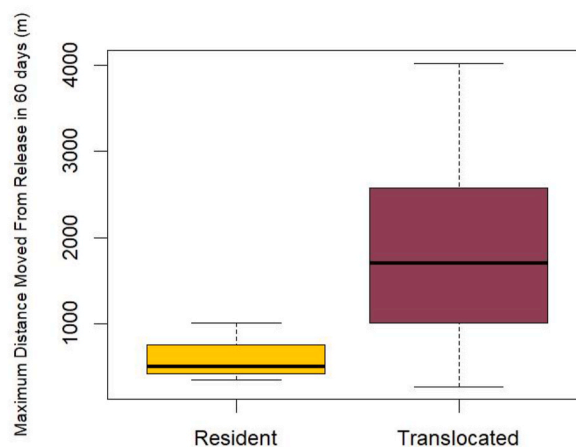
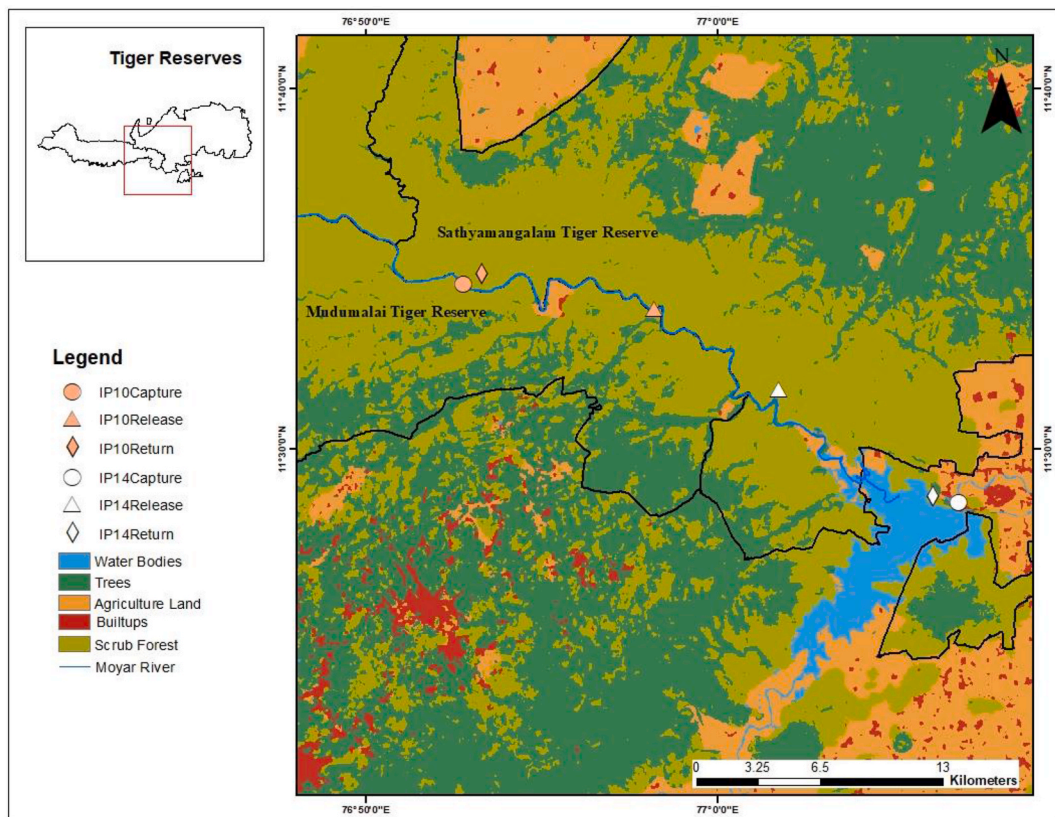


Fig. 2. Post-release movement by resident and translocated pythons within 60 days.

Table 1

Radiotelemetry information on resident and translocated snakes. Snakes are organized in ascending order of translocation distance. Note that the snakes translocated greater than 11 kms failed to navigate in the direction of home. All other translocated snakes moved within the direction of home. *Closest distance to home was not calculated for these snakes because radio-tracking was interrupted by the covid19 pandemic during the first 60 days post release.

ID	Sex	Translocation Distance (m)	Total Tracking Period (days)	Closest Distance to Home w/in 2 months (m)	Closest Distance to Home w/in 2 years (m)	Days to Closest Distance	Proportion of Translocation Distance Returned
IP1	F	0	695				
IP13	F	0	325				
IP12	F	285	493				
IP4	F	1925	592	214	111	157	0.9423
IP11	F	2323	469	1797	86	96	0.963
IP8	M	3128	638	NA*	1021	565	0.6736
IP5	M	3242	397	427	278	95	0.9143
IP6	M	3290	645	1294	1294	32	0.6067
IP7	M	4670	371	657	353	97	0.9244
IP10	M	9931	530	NA*	1078	491	0.8915
IP14	F	10957	291	NA*	1001	289	0.9086
IP9	M	21232	44	20120	20120	44	0.0524
IP2	M	22459	671	22440	22440	20	0.0008
IP3	F	55680	58	55487	55487	15	0.0035

**Fig. 3.** Capture, release, and return location of medium-distance released pythons (9–11 kms).

m farther from their original capture location than the translocation distance). None of the three pythons translocated long distances moved greater than 5 % of the way to their original capture locations (Figs. 4 and 5). However, IP9 was missing for an extended period. IP3's location became inaccessible due to thorny bushes and the high presence of elephants, leading us to avoid tracking in those regions for an extended period. The tracking process caused a substantial time lag for these two individuals. However, we were able to recapture both IP9 and IP3 at the end of the study near the release sites by employing maximum manpower. IP3 was recovered 692 days post-release 2.74 kms from the release location, and IP9 was found 575 days post-release 6.5 kms from the release location.

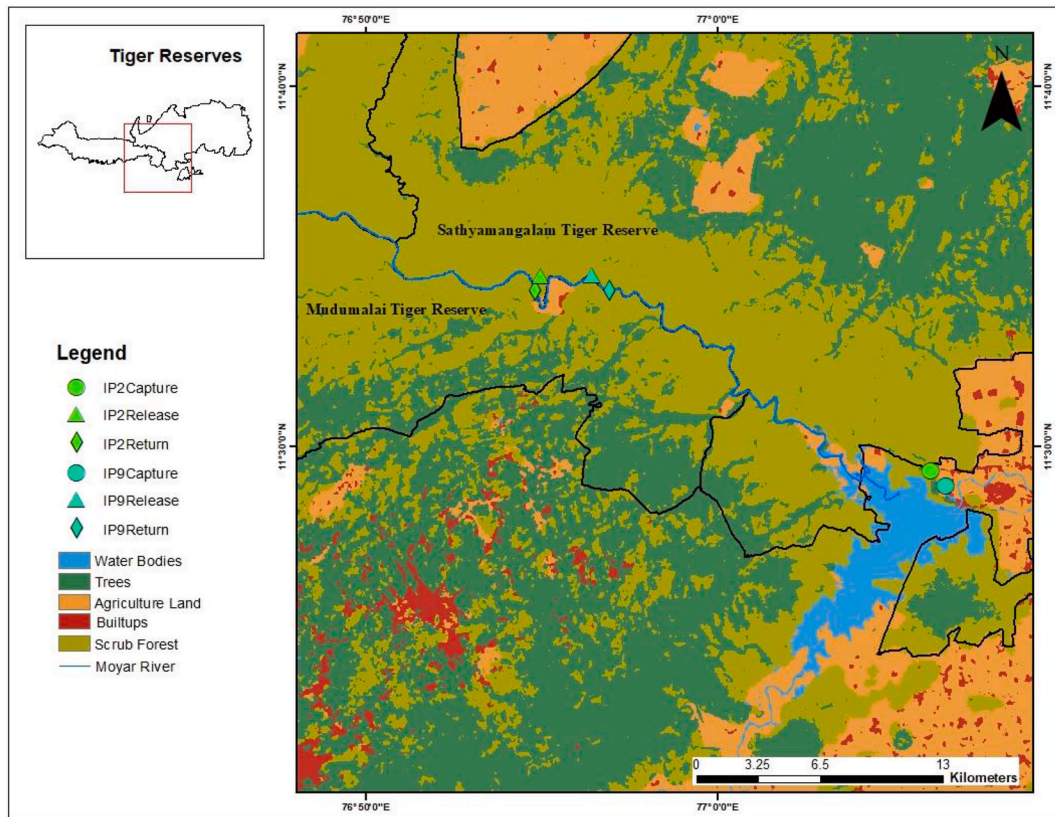


Fig. 4. Long-distance translocations of pythons (21–22.4 kms).

3.3. Long term movement

The three snakes translocated long distances (and did not home) displayed mean daily movement (233 m, $N = 3$) more similar to short and medium-distance translocated snakes (199 m, $N = 8$) than resident snakes (57 m, $N = 3$) (Fig. 4). This result may indicate aberrant or at least increased movement post-release even for snakes that did not successfully home. However, one long-distance translocated snake that was radio-tracked for 671 days was observed to have mated 33 days post-release, likely indicating a return to typical behaviour.

4. Discussion

Translocation is considered a controversial conservation strategy because it can result in increased mortality and aberrant movement patterns of translocated individuals in comparison with resident individuals [13,16,42]. Translocation may have particularly negative consequences for long-lived species with sophisticated navigational capacity or those that depend on local landmarks to navigate. However, long-distance translocation has been used successfully when accompanied by strategies to ensure appropriate habitat is available to translocated organisms and the timing of translocation does not negatively impact the phenology of the species [2].

This study suggests that long-distance translocation may be helpful for the conservation of the Indian python as long as individuals are translocated to high-quality habitat. All three snakes that were translocated between 25 km and 56 km from their capture locations failed to navigate home and remained in proximity to the release locations. None were observed to have displayed aberrant movement patterns, although there is some evidence these snakes may have initially moved more than resident snakes. IP2M was observed to have mated in the new release location, which may indicate a return to normal movement behavior. Additional research is critical for determining the extent to which long-distance translocation impacts the movement behaviour of Indian pythons, since 2 of the 3 long-distance translocated snakes were lost for significant periods of time post release. A similar study conducted in South Carolina, USA, revealed that translocated free-ranging rat snakes (*Pantherophis obsoletus*) exhibited increased movement frequency and space utilization compared to resident snakes initially. However, after a month, the behavior of the translocated snakes converged to resemble that of the resident individuals [43].

Our study showed that translocated pythons displayed greater net movement distances compared to resident snakes within the first 2 months of release. The movement and activity ranges of translocated snakes are likely to be larger than resident snakes due to efforts

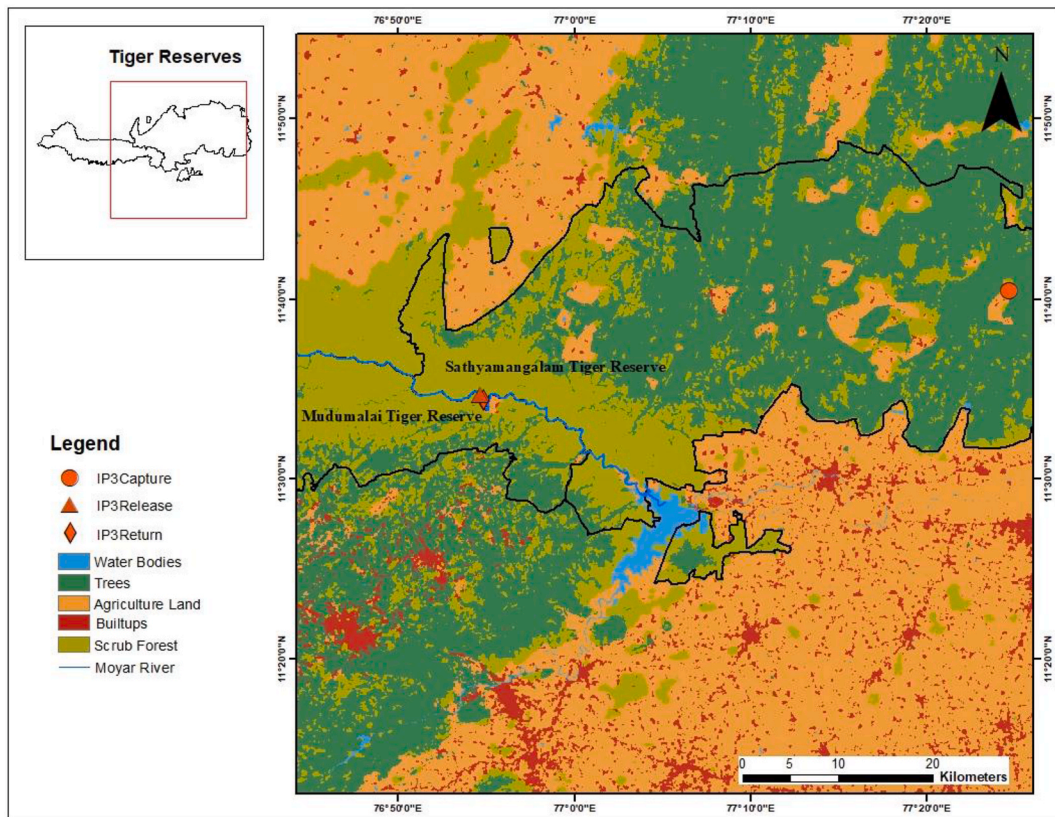


Fig. 5. The longest python translocation IP3 (55.7 kms).

to relocate their original home ranges when perceived as ‘lost’ [44]. Individuals may return to their capture site if the translocation distance is relatively close [44]. For instance, in Florida, USA, invasive Burmese pythons that were translocated up to 36 km away from their capture points exhibited faster and more extensive movements compared to residents. This behavior implied a motivation to return to their established home ranges. Similarly, a translocation study conducted with western rattlesnakes (*Crotalus oreganus*) in British Columbia, Canada, found that 12 out of 14 of these snakes returned to within 500 m of their initial capture site in less than a month following short distance translocation [45].

One hundred percent of pythons translocated short distances (<11 km) successfully navigated at least 60 % of the distance to their original capture locations. Because these pythons navigated back to their capture locations without the memory of an outward path, these snakes displayed a map and compass sense, likely using local cues at the release site to determine their position relative to home. Because these pythons were translocated short distances, they may have also used local olfactory cues or other locally observed landmarks to navigate home. These results suggest that short-distance translocations may generate high homing rates and, therefore, may not significantly reduce human-wildlife conflict over the long term.

The specific cues used by Indian pythons to navigate are not currently understood. Many snakes have navigational capacities that enable them to return to hibernacula and home ranges year after year [46]. This and other translocation studies additionally suggest that some snakes may have the capacity for true navigation, which enables them to determine their position relative to a home location without memory of an outward path [10,45]. Snakes can detect airborne sounds and chemical cues, and are able to develop chemical search images during predatory strikes that are used in subsequent chemosensory searching [47–50]. Therefore, Indian pythons may be using chemical cues to orient themselves relative to home. Navigating over longer distances may require additional cues such as magnetic or celestial cues. An animal’s cognitive abilities significantly impact its overall fitness, influencing reproductive behavior, foraging habits, defence mechanisms, spatial distribution, and migration patterns [51]. Therefore, additional research on snake cognition is critical to a more comprehensive understanding of their ecology and behaviour.

5. Conclusion

The study results indicate that native Indian pythons are capable of homing over distances as great as 11 km, but we did not find evidence that Indian pythons were capable of homing or motivated to home distances as great as those observed in invasive Burmese pythons in South Florida [10]. The experiment suggests longer distance translocations of Indian pythons could disrupt the cues used by snakes navigating shorter distances, and thus prevent successful homing. However, future research should further investigate

strategies to minimize aberrant movement behaviour post translocation.

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Data availability

The datasets used and/or analysed during the current study are available from the corresponding author upon reasonable request. Figures can be accessed at the following link (<https://doi.org/10.6084/m9.figshare.26013721.v1>).

CRediT authorship contribution statement

C.S. Vishnu: Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Investigation, Data curation, Conceptualization. **Chinnasamy Ramesh:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization. **Shannon Pittman:** Writing – review & editing, Validation, Software, Methodology, Formal analysis. **Vedagiri Thirumurugan:** Data curation. **Gautam Talukdar:** Supervision, Investigation, Funding acquisition. **Krishnamurthy Ashokan:** Supervision, Resources. **P.G. Arunlal:** Supervision, Resources. **Veerabadran Naganathan:** Writing – review & editing, Supervision, Resources.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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