1 **Is Long-Distance Translocation an Effective Mitigation Tool for White-lipped Pit Vipers**
2 **(*Trimeresurus albolabris*) in South China?**

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16
17 **ABSTRACT:**

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19 Translocation of ‘nuisance’ snakes is frequently employed on a large scale in densely populated
20 areas in order to mitigate human-wildlife conflict. However, the methods used are often applied
21 haphazardly and are rarely evaluated, especially in tropical Asia. The objective of this study was
22 to assess the effects of long-distance translocation on the white-lipped pit viper (*Trimeresurus*
23 *albolabris*) in South China, where they are routinely removed from urban areas or homes and
24 translocated into national parks. Using radio telemetry, we compared the ecology and biology of
25 ‘resident’ and ‘translocated’ snakes to determine if long-distance translocation (>3 km) is a
26 viable conservation option. Translocation extended the period over which predation occurred and
27 significantly decreased survival. Translocated snakes made unidirectional movements away from
28 points of release, yet these movements were not oriented towards points of origin and there was
29 no evidence for homing behavior. Translocation significantly increased frequency of movements
30 and distances moved by female snakes, but no such differences were observed for male snakes.
31 In contrast with resident snakes, translocated snakes did not show synchrony in the onset of
32 brumation, and translocation appeared to negatively affect reproduction in both males and
33 females. Our results suggest that long-distance translocation is not the best management
34 approach to handle nuisance individuals of this species. Findings of this study can be used to
35 prescribe improvements for current strategies to deal with nuisance snakes in Hong Kong and in
36 the region.

37
38 *Keywords:* human-wildlife conflict; movement patterns; reproduction; sexual dimorphism;
39 survival; Viperidae

1. Introduction

Human encroachment on natural habitats has led to a rise in human-wildlife interactions (Reinert and Rupert 1999), and these interactions are increasingly viewed as conflicting, especially in urban environments (Craven et al. 1998). However, increases in human-wildlife conflict in recent decades have also been accompanied by added pressure from the public to use alternative management methods rather than traditional lethal methods (Massei et al. 2010). As a result, translocation of ‘nuisance’ wildlife – or the assisted movement of conflict animals from their origin to another location – has become the preferred mitigation tool for many agencies (Fischer and Lindenmayer 2000; Massei et al. 2010), and is generally focused on conservation of the species (Treves et al. 2009) rather than simply addressing management of an individual ‘nuisance’ animal.

Translocation is a tool employed in many conflict and non-conflict situations including establishment of populations or reintroduction of threatened or locally extirpated species (Griffiths and Pavajeau 2008; Moorhouse et al. 2009; Tuberville et al. 2005), shielding threatened populations from direct anthropogenic impacts (Armstrong 2008), or introductions of individuals to increase genetic variation in existing populations (Madsen et al. 1999). Success therefore varies widely depending on desired outcomes and parameters examined (Harvey et al. 2013; Pinter-Wollman et al. 2009; Riedl et al. 2008). For example, when used to mitigate conflict that arises from the presence of ‘nuisance’ or unwanted animals, translocation has exhibited lower success than other non-conflict motivated translocations (Germano and Bishop 2009). Unfortunately, translocation for non-conflict purposes is often conflated with conflict mitigation (Sullivan et al. 2014), which can overestimate the latter’s efficacy.

In general, translocation to mitigate ‘nuisance’ animal conflict has not achieved desired outcomes and thus is often not successful (Germano and Bishop 2009; Massei et al. 2010). Despite this, translocation is often chosen over alternate methods, as management policies are often influenced by public pressure rather than being supported by scientific evidence or cost-benefit analysis (Sarrazin and Barbault 1996), even when alternatives may offer more effective long-term solutions (Craven et al. 1998). Many agencies involved in wildlife management are still plagued by a deficiency of supporting data in the published literature arising from poorly documented translocations and the reluctance to publish negative data (Fischer and Lindenmayer 2000; Germano and Bishop 2009).

Reptiles represent a particularly threatened and data-deficient taxon (Böhm et al. 2013; Gibbons et al. 2000), and snakes are of particular interest in human-wildlife conflict mitigation. Translocation of reptiles has been relatively less successful compared to other vertebrates (Dodd and Seigel 1991), and human-wildlife interaction results in a greater likelihood of intentional mortality of snakes compared to other taxa, as they are viewed as potentially dangerous animals (Bonnet et al. 1999; Hardy et al. 2001). Erratic movements in displaced snakes have been documented (Fitch and Hampton 1971; Landreth 1973), and controlled studies on the effects of long-distance translocation on snakes to mitigate human-wildlife conflict have revealed adverse effects on survival and movements (Butler et al. 2005b; Nowak et al. 2002; Plummer and Mills 2000; Reinert and Rupert 1999).

Even with significant efforts to understand the effects of long-distance translocation on snakes, controlled studies have been almost entirely restricted to snakes of North America and Australia (but see Barve et al. 2013; Lee and Park 2011). The effects of translocation on Asian snake taxa remain understudied, even though translocation is widely used in tropical Asia as a

tool to alleviate human-wildlife conflict (Barve et al. 2013). Our limited understanding of the effects of translocation on these snakes is alarming considering the human and capital costs associated with snake management programs.

The overarching goal of this study was to determine if long-distance translocation is a viable conservation option for the white-lipped pit viper (*Trimeresurus [Cryptelytrops] albolabris*). Our objectives were to compare survival, movements, reproduction, and brumation between ‘resident’ and ‘translocated’ snakes. Besides being one of the most commonly translocated snakes in Hong Kong (KFBG, unpublished data), *T. albolabris* is by far the most common cause of medically-significant snakebite injury in Hong Kong (Hon et al. 2004), and an assessment of current and alternative management strategies is pertinent from mitigation, conservation and public health perspectives.

2. Methods

Trimeresurus (Cryptelytrops) albolabris is a relatively small, sexually dimorphic arboreal pit viper that is distributed widely in South and Southeast Asia (Karsen et al. 1998). Females attain body sizes up to 950 mm in total length, and males up to 620 mm in total length (Devan-Song, unpublished data). Very little published information exists on its life history and ecology, although Orlov et al. (2002) report details on populations in Northern Vietnam.

We conducted this study from May to December 2012 and June to December 2013 in the Hong Kong Special Administrative Region of China (2209’-2237’N, 11350’-11430’E). Although Hong Kong contains high-density urban areas, much of the land comprises rural area and small villages within or near 23 national parks (known as Country Parks). Approximately 40% of the 1,100km square land area is protected within national parks. This proximity of high human population densities and natural sub-tropical forests creates conditions that lead to human-wildlife conflict.

In Hong Kong, ‘nuisance’ snakes are generally those that find their way into or near houses or businesses and are captured by snake handlers employed by the Hong Kong Police. Snakes are transported to Kadoorie Farm and Botanic Garden (KFBG), a privately funded conservation organization and are examined by a snake expert before considering re-release up to 50 km from capture site. We obtained study snakes (hereafter ‘translocated snakes’) from KFBG that had been transported from districts all over Hong Kong. We captured resident snakes during visual encounter surveys conducted along hiking trails in the Sai Kung and Ng Tung Chai districts of Hong Kong.

We transported translocated and resident snakes to the Veterinary Hospital of Ocean Park Corporation and anesthetized them using vaporized Isoflurane, an inhalant anesthetic. Radio transmitters (SB-2 or BD-2, Holohil Systems Ltd., Carp, Ontario, Canada) weighing no more than 6% of the body mass of the snakes were surgically implanted into the coelomic cavity and antennae were threaded subcutaneously, following Reinert (1992) and Hardy and Greene (1999). During surgery, the following data was obtained from sedated snakes: snout-vent length, body mass, and presence, number and length of ovarian follicles or embryos in females using ultrasonography (Esaote Mylab™ 35, Indianapolis, Indiana, USA). Vipers were allowed at least two days for recovery. Translocated snakes were released between 3 – 30 km from point of capture, and resident snakes were released at exact point of capture. We defined ‘long-distance translocation’ as translocating a snake outside of its estimated home range, using Shine et al.’s

(2003) study on the similar-sized *Gloydius shedaoensis* to estimate home ranges of closely-related pit vipers as no prior information on *Trimeresurus* home ranges exist. In 2012, we released translocated snakes in mixed shrubland/grassland/abandoned agricultural ponds habitat (hereafter referred to as shrubland) at a commonly-used KFBG translocated site, in order to mimic the translocation program. Resident snakes of 2012 were captured in lowland mixed broadleaf evergreen secondary forest (hereafter referred to as woodland). Elevations of both types of habitats were comparable (< 100 m elev.). In 2013, translocated snakes were released in commonly-used KFBG translocated sites in woodland within 5 km of 2013 resident sites, hence habitat type for both groups were highly similar lowland (< 100 m elev.) woodland.

We located all vipers two to three times per week except during tropical cyclone periods, when vipers were relocated once a week. We recorded snake locations using a global positioning system. We recorded brumation and defined 'onset of brumation' as the period between the time a snake was last found above ground, and the first time it was discovered under leaf litter, soil, or rock debris. If the individual survived to the end of the transmitter battery life (14 to 20 weeks), the snake was recaptured and the transmitter was replaced. All survivors were recaptured, had their transmitters removed under anesthesia, and were released at the last point of capture after two days of recovery.

2.1 Data analysis

We used Kaplan-Meier survival estimates to calculate survival rates of resident and translocated snakes over the study periods, and compared survival between translocated and resident snakes using a log-rank test. We extrapolated survival to annual survival using the following formula: $annual\ survival = K^{52/x}$, where K = Kaplan-Meier estimate of survival over study period, and x = number of weeks over which snakes were radio-tracked.

We quantified differences in movements between resident and translocated snakes with three different metrics. First, trajectories were drawn for individual snakes using straight lines between consecutive GPS coordinates obtained during relocations. We used a test of independence to test for sequential autocorrelation in linear parameters, or unidirectionality of movements (Calenge 2006). We compared proportions of snakes that made unidirectional movements between resident and translocated snakes with a Fisher's exact test. We also determined if translocated snakes were homing using the following equation:

$$Orientation\ Efficiency = (D_i - D_f)/L,$$

where D_i = displacement distance, D_f = distance between last point of trajectory and original home, L = path length (Bodin et al. 2006). We determined if the average orientation efficiency was positive and different than zero using a one-tailed t-test.

For the second movement analysis, we calculated the frequency of movement for each snake by dividing the total number of times a snake moved > 5 m in between relocations by the total number of relocations for that individual. This threshold was chosen based on the accuracy distance reported by the GPS unit used. For females, we compared movement frequencies, using experimental group (translocated, resident) and year (2012, 2013) as factors, with a two-way analysis of variance. We only used snakes that had been tracked for more than eight weeks. We compared frequency of movement between translocated and resident males using a Student's t-test.

For the last movement analysis, we calculated the average daily movements of each snake by dividing the total distance moved over the active season by the total number of days tracked over the active season. We only used snakes that had been tracked for more than eight weeks. We defined ‘active season’ as the period of time when snakes were not brumating. For females, we compared average daily movements, with experimental group (translocated, resident) and year (2012, 2013) as factors, with a two-way analysis of variance to. For males, which were only tracked in 2013, we used a Student’s t-test to compare average daily movements of translocated and resident snakes.

Data were log-transformed if they failed to meet assumptions of equal variance and normality of residuals for analysis of variance. All averages are reported with standard errors (SE). Statistical analyses were conducted in R 3.0.2 (R Development Core Team 2014). We used ArcGIS 10.1 (ESRI, Redlands, California, USA) for visualization of spatial data.

3. Results

We radio-tracked 18 females (nine resident, nine translocated) between May and December 2012 and 15 females (seven resident, eight translocated) and eight males (four resident, four translocated) between June and December 2013 (Fig. 1). Different snakes were tracked between years. We obtained a total of 1245 locations of 41 snakes over 2012 and 2013. We did not observe any mortality arising directly from handling, sedation, surgery or transport.

3.1. Survival and mortality

In 2012, survival (0.342) for female resident snakes over 31 weeks was similar (0.333) to that of translocated snakes over 18 weeks (Fig 1), however statistical comparisons were not conducted as duration of tracking periods differed. In 2013, resident snakes had a higher probability ($\chi^2 = 5.27$, d.f. = 1) of survival (0.71) over the 26-week study period than did translocated snakes (0.25). All surviving translocated snakes were female, as all four translocated males died before the end of the project. We extrapolated survival over a year to obtain annual survivorship, and translocated snakes exhibited extremely low annual survival (0.042 in 2012 and 0.063 in 2013) compared with that of resident snakes (0.165 in 2012 and 0.499 in 2013).

We documented higher levels of mortality in translocated snakes than in resident snakes (Table 1). Predation was by far the most common cause of death among the two groups, however a higher percentage of translocated snakes were predated (Table 1). Additionally, four of the 21 translocated snakes died under unusual circumstances and cause of death could not be determined (Table 1). Two of these translocated individuals were found as intact healthy carcasses, and necropsies revealed no underlying infection, disease or injury (Table 1).

We documented temporal differences in dates of predation between resident and translocated snakes. All five predation events of resident snakes (three in 2012 and two in 2013) occurred within two weeks in October, but predation events occurred in translocated snakes over more than four months from 10 July to 19 November (Table 1).

3.2. Movements

Translocated snakes were far more likely to make unidirectional movements than resident snakes ($\chi^2 = 4.73$, df = 1, P = 0.030). None of the 16 resident trajectories displayed non-independent sequential linear parameters, indicating that their movements were not uni-directional. In

contrast, trajectories for six (one male, five females) of the 17 translocated snakes exhibited non-independent linear parameters, which indicated uni-directional patterns of movement (Figs. 2 and 3). Of these five females, two were translocated in woodland and three in shrubland. Translocated snakes had an average orientation efficiency of 0.010 ± 0.126 . We found no evidence of homing in translocated snakes ($t = 0.12$, $df = 18$, $P = 0.452$), indicating that their trajectories, although unidirectional in some cases, were not orientated toward points of origin.

Female translocated snakes exhibited movement patterns that differed from those of resident snakes, but males did not. Regardless of year tracked, translocated females moved more frequently than resident females ($F = 8.440$, $df = 1$, 24 , $P = 0.008$, Fig. 4A), and females tracked in 2012 moved more frequently than those tracked in 2013 ($F = 4.95$, $df = 1$, 24 , $P = 0.036$). There was no interaction between experimental group and year in frequency of movements among females ($F = 0.19$, $df = 1$, 23 , $P = 0.670$). Regardless of year tracked, translocated females moved larger distances per unit time than resident females ($F = 17.32$, $df = 1$, 23 , $P < 0.001$, Fig. 4B), in both years ($F = 2.66$, $df = 1$, 23 , $P = 0.117$). We found no interaction between experimental group and year in average daily movements by females ($F = 3.10$, $df = 1$, 22 , $P = 0.092$). We found no difference in frequency of relocations between translocated and resident males ($F = 0.885$, $df = 1$, 6 , $P = 0.383$, Fig. 5A). Average daily movements did not differ between translocated and resident males ($F = 0.29$, $df = 1$, 6 , $P = 0.610$, Fig. 5B).

3.3. *Reproduction and brumation*

Our results from 2013 suggest that reproduction is disrupted by translocation. Of the five surviving resident females in 2013, two were undergoing stage II-II vitellogenesis in December, suggesting preparation for ovulation the following spring. In contrast, all three surviving females of 2013 still displayed primary follicles in December and were unlikely to be preparing to reproduce the following spring. All four translocated males died well before the end of the mating season, and are far less likely to have mated than resident males, two of which survived to the end of the project.

We observed differences in brumation patterns between resident and translocated snakes. In 2012, all three surviving females found brumation refugia on the ground between 6th and 18th December, yet only one of the three surviving translocated females displayed brumating behavior. The other two translocated females were still active in the vegetation above ground until the end of the 2012 study period. In 2013, all surviving translocated females and all surviving resident females moved to brumation refugia. The onset of brumation overlapped for resident and translocated snakes, however, the onset period for translocated snakes was much longer. In 2013, all resident snakes commenced brumation between 4th and 12th December, while in contrast, the date of onset of brumation for translocated snakes ranged from 16th November to 30th December. None of the resident males brumated, however comparisons cannot be made as no translocated males survived to winter.

4. Discussion

There is a growing body of research detailing the negative impacts of long-distance translocation on snakes, and our results are congruent with previous studies in which survival or movements or both are negatively impacted by long-distance translocation (Butler et al. 2005a; Nowak et al. 2002; Plummer and Mills 2000). We found that translocation resulted in lower survival rates in *T. albolabris*, extension of period over which predation takes places, aberrant movement patterns

of females, impaired navigational capacity and response to environmental stimuli for brumation, and reduced reproductive capacity.

Translocation was clearly associated with reduced survival in 2013, while unequal tracking periods in 2012 prevented a statistical comparison. Extrapolated over a year, however, survival in resident snakes was starkly different from that of translocated snakes in both years. This difference may also be underestimated because of temporal differences in predation risk. That is, resident snakes appeared to be at risk only a few weeks of the year, while translocated snake predation occurred throughout the study period.

Translocation resulted in aberrant movement patterns in *T. albolabris*. We documented a higher likelihood of unidirectional movements away from point of release, but these unidirectional movements were not oriented to the snakes' points of origin, as we found no evidence for homing in translocated snakes. Burmese Pythons (*Python bivittatus*) have been found to orient towards point of origin after being displaced (Pittman et al. 2014), and several long- and short- distance snake translocation studies report that individuals made straight-line or parallel movements before eventually returning home (Brown et al. 2009; Hare and McNally 1997; Nowak et al. 2002; Reinert and Rupert 1999). However, we found no relationship between directional movements of translocated *T. albolabris* and place of origin. Unidirectional movements made by translocated vipers may instead be driven by fleeing from the point of release or exploration to find a new home range, without navigational cues influencing direction of travel.

Translocation appeared to severely affect movements of female snakes, but not those of male snakes, although differences in sex ratios and unequal sampling periods resulting from the premature death of all translocated males prevented us from teasing out any relationships between experimental group and sex. Translocated females displayed different movement patterns than those of resident females for all movement metrics assessed, with a clear trend of higher frequency of movement and larger distances moved per unit time. The aberrant and highly variable movements observed in translocated *T. albolabris* were consistent with movements following long-distance translocations in other snake taxa (Butler et al. 2005b; Lee and Park 2011; Plummer and Mills 2000; Roe et al. 2010). Increases in the frequency of movements and distances moved by snakes are strongly correlated with increased risk of predation (Bonnet et al. 1999; Madsen and Shine 1993), and results from this study on *T. albolabris* suggest a positive relationship between increased movements and increased predation. Although we have no data available on microhabitat selection, we cannot rule out that inadequate territory use, basking, and ambush site selection by translocated snakes could also contribute to higher detection by predators and lead to higher mortality in these snakes.

As opposed to female snakes, male movements appeared to be unaffected by translocation. We hypothesize that natural movements of resident males put them at greater risk of mortality because of predators and other sources, as small-bodied males make very large mate-searching movements, compared to more sedentary, heavy-bodied females. Movement in snakes is energetically costly (Gregory et al. 1987), and this appears to be particularly true in male *T. albolabris*. A translocated male will therefore have to cope with the increased energy demands associated with translocation, in addition to the already highly taxing energy requirements needed for mate-searching movements. On the other hand, adult females have more substantial fat reserves than males and therefore may have higher capacity for embarking on translocation-induced changes in movement than males.

Translocation negatively affected reproduction in female snakes, but we were unable to predict the reproductive fates of male snakes that survive translocation as no translocated males survived to the end of the project. Female *T. albolabris* breed once every two or more years, except for very large females which may reproduce in consecutive years (A. Devan-Song, unpublished data). In 2013, large translocated females, despite not gestating and having gained substantial mass over that year, did not undergo vitellogenesis, when their resident equivalents were doing so. The earliest ovulation and gestation season that these translocated females would participate in is summer 2015, two years after the end of the project, as an individual preparing to ovulate in summer 2014 would have already commenced vitellogenesis in winter 2013. Given low survival rates we documented, the chances of translocated snakes surviving one, let alone two years, is very slim, and overall prospects for reproduction by translocated females are bleak.

As with reproduction, our comparison of brumation in translocated and resident snakes is only possible for female snakes as no males survived. Brumation is an important life history event that snakes employ to survive the harsher conditions of winter in seasonal climates (Gregory 1982). For example, in a study examining repatriated and translocated massasauga snakes (*Sistrurus catenatus*), 100% of snakes that did not hibernate died over winter (Harvey et al. 2013), and dormancy appears to be critical for thermoregulation and survival especially in colder climates. In our study, brumation in female translocated snakes was unsynchronized, and two translocated snakes did not appear to brumate, suggesting reduced ability to respond to environmental cues, and provides insight as to how translocation may affect cognition in snakes. Translocation has been shown to increase the medial cortex volume in rattlesnakes in response to increased navigational demands (Holding et al. 2012), and other cognitive processes such as response to external stimuli may be affected by these neurological changes. *Trimeresurus albolabris* is a solitary species with no communal hibernation or apparent cues from conspecifics as to locations of refugia, unlike several rattlesnake species (*Crotalus*), which trailed conspecifics to locate hibernacula in their new sites in translocation experiments (Nowak et al. 2002; Reinert and Rupert 1999). Reduced brumation initiation as well as unsynchronized brumation in translocated snakes may reflect this solitary brumation aspect of *T. albolabris*, wherein translocated snakes are unable to find hibernacula by trailing resident conspecifics, and provides further evidence for the unsuitability of this species for long-distance translocation.

There were too few translocated survivors each year in this study to compare changes in mass over the active season. However, 4 out of the 6 total translocated survivors increased in mass over the active season, and this appeared unrelated to vitellogenesis or brumation patterns. Study group also did not appear to have a clear correlation with presence of fat bodies in dead necropsied snakes, with depleted fat reserves in some resident snakes, while some translocated snakes still retained fat bodies (Table 1). Additionally, previous translocation studies have also reported little correlation between translocation and loss of weight in snakes (e.g. Reinert and Rupert 1999), and it is likely that much larger sample sizes and multiple data points for each individual is necessary to draw any conclusions on the effects of translocation on body condition.

It is worth noting that key results of other translocation studies suggest that common and widespread species (Griffith et al. 1989) and sedentary ambush predators (Plummer and Mills 2000; Shine and Fitzgerald 1996) may be less affected by translocation than other species. However, our results show the opposite, despite *T. albolabris* fulfilling both criteria. We suggest the relative severity of translocation effects on *T. albolabris* compared to that of other snake taxa results from a low background survival rates in resident populations compared to that of other pit vipers. The eightfold decrease in annual survivorship in translocated snakes observed in 2013 is

more severe than that of translocated rattlesnake species, which display a two to threefold decrease (Hare and McNally 1997; Nowak et al. 2002; Reinert and Rupert 1999) or in tiger snakes (*Notechis scutatus*) which had no discernable difference in survival over a six-month study period (Butler et al. 2005a). The only published study reporting decreases in survival of the magnitude we observed in 2013, was in the Eastern hognose snake (*Heterodon platirhinos*) (Plummer and Mills 2000). This suggests that snake species exhibiting naturally low survival probabilities may be more adversely impacted by translocation. Notably, the aquatic northern water snake (*Nerodia sipedon*) has resident survival probabilities similar to those of *T. albolabris* and *H. platirhinos*, yet this species' survival is not as severely affected by translocation as the latter two (Roe et al. 2010). However, there is evidence that reptiles constrained by habitat preference (such as highly aquatic species) are less likely to stray from translocated release sites, and are therefore better candidates for translocation (Attum et al. 2013). The results of this study suggest that snakes with little habitat specificity and low natural survival levels may respond poorly to translocation compared to other snake taxa, and translocation programs should take into account natural survival and life history traits of species targeted for translocation.

All results indicate that translocation is an ineffective tool for resolving human-wildlife conflict involving *T. albolabris*, however, problems associated with translocation extend beyond displaced individuals. Negative effects on recipient resident populations must also be considered in translocation programs. Genetic outbreeding is one possible negative effect of sustained long-distance translocation (Weeks et al. 2011; Whiting 1997), as is the risk of introducing pathogens from translocated individuals to resident populations (Cunningham 1996; Dodd and Seigel 1991; Kock et al. 2010; Viggers et al. 1993). Finally, potential effects on the behavior, populations and distributions of prey in translocation sites may be of concern, although we have little information on the diet of *T. albolabris* (and many other commonly-translocated snakes in the region).

Based on the results of our study, we believe that long-distance translocation is not an effective conservation option for *T. albolabris* in Hong Kong, and alternatives for conflict vipers need to be examined. While we were unable to estimate fiscal costs of translocation in Hong Kong, an average of 818 snakes a year were rescued by KFBG between 2011-2015, 13.5% of which were *T. albolabris* (KFBG, unpublished data). This resulted in approximately 11 person hours per week spent on snake rescue between May and October of these years, excluding time and resources spent by the Hong Kong Police on rescues from properties (KBFG, unpublished data). Resources may therefore be better spent on methods that have successful aspects to them, such as short distance translocation (Brown et al. 2009), or even 'soft' releases (see Kingsbury and Attum 2009; Tuberville et al. 2005). Future research can focus on examining the efficacy of alternate methods for *T. albolabris* and snakes with similar habits.

Although this study focused on *T. albolabris*, the negative effects we observed may also extend to species with similar life history traits, including other members of the genus *Trimeresurus*, many of which are also widespread and relatively commonly encountered (Malhotra and Thorpe 1997; Orlov et al. 2002) and are likely to be conflict snakes within their ranges. Our results are also applicable to non-conflict situations such as reintroduction, repopulation and possibly repatriation, if the differences between sources of snakes are taken into account. Although non-conflict translocation is motivated by different reasons and results are often assessed at the population and not individual level, our results along with those of previous studies suggest lower survival and reduced fecundity for adult snakes, which can render conservation-motivated translocation a wasted effort, particularly in rarer species or those with restricted distributions.

Acknowledgements

We are grateful to D. Willott for access to sites and locating of vipers for this project, and L. Ng and for assistance with logistics and equipment. Field assistance was provided by L. Tirrell, M. Low, R. So, S. Yue, K. MacIntosh, M. Strimas-Mackey, L. Glidden, R. O'Brien, A. Saenger and N. Jakubek. We thank N. Fernando, Lee F. K., W. Chan, G. Kwok, J. Sievwright and J. Heung at the Veterinary Department of Ocean Park Corporation. We appreciate manuscript edits from L. Gonzalez, J. Kolbe and three anonymous reviewers. Additional field assistance and site selection was provided by Y. Wong, R. Ferguson, J. Ferguson, S. Ferguson, K. Caldwell, E. Caldwell, D. Rosenberg, S. Loman, W. Sargent, A. Bizid, K. Messenger and R. Wright. The animal welfare protocol (11-1083) was approved by the Animals Control of Experiments Ordinance, Department of Health, and the Veterinary Hospital of Ocean Park Corporation; provision and translocation of rescued wild snakes approved by the Fauna Conservation Department of Kadoorie Farm and Botanic Garden Corporation; a research permit (collection permit 40) was approved by the Agriculture Fisheries and Conservation Department of the Hong Kong Government. We are grateful for funding provided by the Research Grants Council of Hong Kong (Grant #767109 and 765510M), USDA National Institute of Food and Agriculture - McIntire-Stennis Program (RI00MS-978-INT), and the College of the Environment and Life Sciences, University of Rhode Island.

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Table 1. Dates tracked, causes of death and necropsy notes of all *Trimeresurus albolabris* mortalities. If clean transmitters were found, the cause of death was determined to be ‘unknown predator’. If a transmitter was found unreground or under dense vegetation and covered in uric acid, cause of death was ‘snake predator’.

		Dates tracked	Sex	Cause of Death	Necropsy
Resident	2012	17 Jun—2 Aug	F	Vehicle	(1)
		3 Aug—16 Oct	F	Infection/disease; cause of infection inconclusive	(2)
		17 Aug—20 Oct	F	Snake predator	
		15 Sep—20 Oct	F	Unknown predator	
		20 Sep—7 Oct	F	Snake predator; tracked to King Cobra	
	2013	25 Jul—10 Nov	F	Apparent starvation; unable to necropsy; desiccated carcass	
		25 Jul—15 Oct	F	Snake predator	
		20 Jul—8 Oct	M	Unknown predator	
Translocated	2012	30 May—10 Jul	F	Unknown predator	
		29 Aug—6 Oct	F	Mammalian predator; euthanized	(3)
		29 Aug—17 Sep	F	Unexplained circumstances; cause of death inconclusive	(4)
		29 Aug—3 Oct	F	Unexplained circumstances- intact desiccated carcass	
		12 Sep—23 Sep	F	Unknown predator	
		26 Sep—19 Nov	F	Mammalian predator	(5)
	2013	14 Jun—15 Aug	F	Snake predator	
		6 Jul—22 Aug	F	Unknown predator	
		18 Aug—20 Sep	F	Vehicle- flattened carcass	
		18 Aug—29 Oct	F	Unknown predator	
		18 Aug—10 Oct	F	Unknown predator	
		25 Jun—9 Sep	M	Unknown predator	
		25 Jul—4 Oct	M	Unexplained circumstances; found partially dead, eaten alive by ants- euthanized.	
		26 Jul—8 Oct	M	Unknown predator	
		24 Jul—24 Oct	M	Unexplained circumstances- intact desiccated carcass	(6)
(1) Blunt trauma to head. No underlying disease or infection of lung, liver or GIT. No food in GI tract, small amount of fat bodies present.					
(2) Minor active congestion and discoloration of liver. Kidney healthy. No food in GI tract. Intissueption of small intestine. Potential inflammation of fat bodies by transmitter					
(3) Thick necrotic ulcers with underlying hemorrhage around bite wounds, hemorrhagic discoloration to liver, spine broken, snake unable to move					
(4) No gut content, small amount of feces in distal gut. No lesions in liver or lung. No inflammation from antenna. Healthy stomach and kidney tissue. Intracoelomic fat present. No evidence of trauma.					
(5) Head and anterior third of body missing; skin pushed back over body therefore mammalian predator, lesion and bruising pre-mortem, abundant abdominal fat; kidneys healthy					
(6) No gut content or feces. No lesions in liver or lung. No inflammatory reaction from transmitter. Healthy stomach and kidney tissue. Small amount of intracoelomic fat. No evidence of trauma.					

575 **Figures**

576 Figure 1: Sample sizes, tracking periods, and Kaplan-Meier estimates of survival for translocated
577 and resident *Trimeresurus albolabris* in Hong Kong. Asterisk indicates significant difference
578 between translocated and resident snakes. No analysis was performed on 2012 data as survival
579 estimates were recorded for different time periods.
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 583 Figure 2: Movement trajectories for resident female (n = 12) and translocated female (n = 13)
 584 *Trimeresurus albolabris* in Hong Kong. Each line represents one individual, and all trajectories are
 585 displayed in the same geographical scale. Asterisks (*) indicate the start of trajectories that were
 586 autocorrelated for sequential linear parameters.

Figure 3: Movement trajectories for resident male ($n = 4$) and translocated male ($n = 4$) *Trimeresurus albolabris* in Hong Kong. Each line represents one individual, and all trajectories are displayed in the same geographical scale. Asterisks (*) indicate the start of trajectories that were autocorrelated for sequential linear parameters.

Figure 4: (A) Frequency of movements (proportion of relocations where a snake moved >5 m); and (B) average daily movements for translocated and resident female *Trimeresurus albolabris* in Hong Kong in 2012 and 2013.

Figure 5: (A) Frequency of movements (proportion of relocations where a snake moved >5 m); and (B) average daily movements for translocated and resident male *Trimeresurus albolabris* in 2013.