

Use of home range behaviour to assess establishment in translocated giraffes

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Abstract

Conservation translocation is a management technique employed to introduce, re-introduce or reinforce wild animal and plant populations. Giraffe translocations are being conducted throughout Africa, but the lack of effective post-translocation monitoring limits our ability to assess translocation outcomes. One potential indicator of translocation success is the establishment of characteristic movement and home range behaviour in the new location. We analysed the post-translocation movement patterns of six Global Positioning System-collared Angolan giraffes (*Giraffa camelopardalis angolensis*) in three regions of Namibia. We estimated home range size with minimum convex polygon (MCP) and adaptive local convex hull estimators, and assessed home range behaviour with the localizing tendency model and a home range Monte Carlo bootstrap analysis. Four of the six giraffes appeared to establish home ranges, indicating short-term translocation success. The other two giraffes exhibited long-distance linear movements throughout the observation period, suggesting they did not establish home ranges. Home range sizes varied greatly among regions. Our results suggest monitoring translocated animals for the establishment of characteristic movement behaviour could be a useful early indicator of translocation success.

Key words: *Giraffa camelopardalis angolensis*, home range, movement behaviour, post-translocation monitoring, site fidelity, translocation

Résumé

La translocation à des fins de conservation est une technique de gestion employée pour introduire, réintroduire ou renforcer des populations sauvages de plantes ou

d'animaux. Des translocations de girafes ont lieu dans toute l'Afrique, mais le manque de suivi après ces translocations limite nos possibilités d'en évaluer les résultats. Un indicateur possible du succès d'une translocation est l'établissement de déplacements et de comportements territoriaux caractéristiques au nouvel endroit. Nous avons analysé le schéma des déplacements après translocation de six girafes d'Angola (*Giraffa camelopardalis angolensis*) équipées de collier GPS dans trois régions de Namibie. Nous avons estimé la taille de leur domaine vital avec la méthode du polygone convexe minimum et des estimations du polygone convexe adaptées à la situation locale et nous avons évalué le comportement territorial avec le modèle de tendance de localisation et une analyse de *bootstrap* (inférence statistique) de Monte Carlo. Quatre des six girafes semblaient établir un domaine vital, ce qui indique une réussite rapide de la translocation. Les deux autres ont présenté de longs déplacements linéaires pendant toute la période d'observation, ce qui suggère qu'elles n'ont pas établi de territoire. La taille des domaines vitaux variait beaucoup selon les régions. Nos résultats suggèrent que le suivi, chez des animaux déplacés, de l'établissement d'un comportement de déplacement caractéristique pourrait être un indicateur précoce utile du succès d'une translocation.

Introduction

Conservation translocation is the intentional movement of organisms from one site to another for conservation benefit (IUCN SSC, 2013). Translocation has been used to address a broad range of goals: assisted colonization, the introduction of a species outside of its historical range; reinforcement, the supplementation of existing populations

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to increase viability; and reintroduction, the release of individuals into an area from which they were extirpated (Seddon, 2010). Motivations for translocations include reducing the risk of local extirpation (White, McClean & Woodroffe, 2003), restoring ecosystem function (Ripple & Beschta, 2004; Gibbs, Marquez & Sterling, 2008), removing individuals from threats and reintroducing a species extinct in the wild (Spalton, Brend & Lawrence, 1999). In addition to conservation goals, translocations may be used to reduce economic losses due to human–wildlife conflict and to increase economic opportunities by creating the potential for wildlife tourism, hunting and game farming (Craven, Barnes & Kania, 1998; Castley, Boshoff & Kerley, 2001; Chipman *et al.*, 2008).

Conservation translocations have had mixed results (Wolf *et al.*, 1996; Seddon *et al.*, 2014). Although the definition of success depends upon the initial goals of the translocation, one common goal is the establishment of a self-sustaining population (Fischer & Lindenmayer, 2000). The timescale for evaluating success for this goal may be protracted, particularly for long-lived species.

Armstrong & Seddon (2008) divide reintroduction into establishment and persistence phases. Under IUCN guidelines, translocations should only be attempted to areas with sufficient resources for the animals' survival and reproduction (IUCN SSC, 2013). One indicator that these criteria are met in the new environment is the establishment of characteristic species-specific movement behaviour, including the establishment of a home range. A home range was originally defined as the 'area traversed by the individual in its normal activities of food gathering, mating and caring for young' (Burt, 1943). Thus, the establishment of a home range following translocation is an indication that the new environment satisfies the individual's resource needs.

Changes in laws addressing ownership of wildlife have led to a marked increase in wildlife translocations across southern Africa (Osofsky *et al.*, 2005; Goss & Cumming, 2013). The IUCN has defined scientifically rigorous guidelines for translocations that include collecting baseline data, risk analysis and post-translocation monitoring. We support these guidelines yet also recognize that many translocations will not fully comply with these guidelines due to limitations of resources or expertise (c.f. Spear & Chown, 2009; Castley, Boshoff & Kerley, 2001). Increasingly, due to advances in technology and reductions in price, a subset of translocated animals are fitted with

Global Positioning System (GPS) collars (Fernando *et al.*, 2012). Data from these collars are often not formally analysed. As rigorous post-translocation monitoring is uncommon, it is useful to examine the degree to which collar data can be used even in the absence of more detailed ecological data regarding resources in the release area.

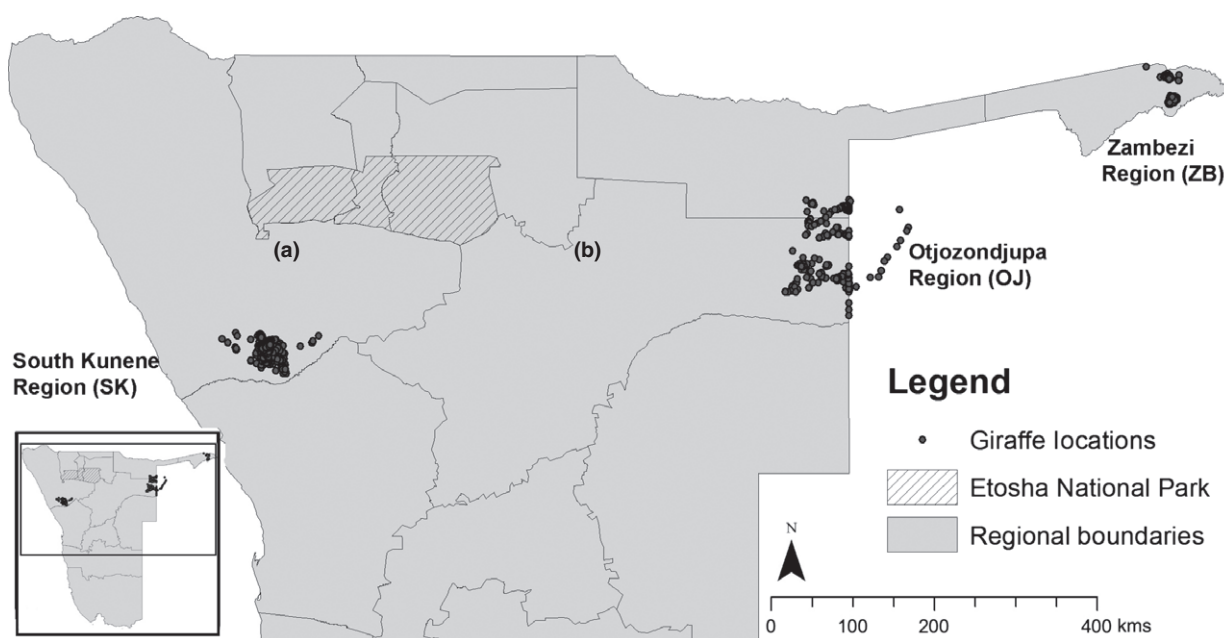
Post-translocation movement behaviour varies across individuals and taxa (Tsoar *et al.*, 2011). Translocated animals may fail to exhibit site fidelity to the release area, which is a common cause of early translocation failure (Dickens *et al.*, 2009). In some cases, this behaviour is due to the individual's attempt to home to its region of capture (Fernando *et al.*, 2012). In other cases, in the absence of homing, the animal nevertheless wanders away from the release site, likely signifying it has found the habitat unsuitable (Dickens *et al.*, 2009). When animals do establish home ranges near release sites, post-translocation monitoring across a broad range of taxa has demonstrated that translocated animals' home ranges are often larger than those of resident animals (Fernando *et al.*, 2012), perhaps as a result of initial exploratory movements to gain knowledge of their surroundings (Kemink & Kesler, 2013).

Here, we examined the post-translocation movement behaviour of the Angolan giraffe (*Giraffa camelopardalis angolensis*) in Namibia. Prior studies suggest that giraffe movements are influenced by a suite of environmental characteristics, including the abundance and distribution of forage and water, climate, topography, intraspecific competition, predators, poaching, urbanization and other human disturbances (Van Der Jeugd & Prins, 2000; Fennessy, 2009). Giraffes exhibit extremely variable home range sizes, differing by a factor of 1000 across Africa (95% minimum convex polygon; Fennessy, 2009; Van Der Jeugd & Prins, 2000). In arid, unproductive environments, such as the Namib Desert, giraffes exhibit large home ranges (maximum 1773 km²; Fennessy, 2009). In more productive areas, such as Lake Manyara National Park, Tanzania, home ranges are much smaller (minimum 0.1 km²), likely due to abundant browse (Van Der Jeugd & Prins, 2000).

In Namibia, extensive giraffe translocations have been conducted into communal conservancies over the last decade. These conservancies have arisen from Namibian policy that conveys management rights over wildlife to local communities on communal land (Lindsey, Romanach & Davies-Mostert, 2009). During 2011 and 2012, 179

Table 1 Collar summary information about the six translocated giraffes. One fix per day of data collection was analysed

ID	Sex	Capture site	Release region	Start date	End date	Duration of data collection (days)	No. giraffes in release group	Fate
ZB1	F	Etosha NP	Zambezi	28 September 2011	Sept. 19, 2012	358	11	Signal failure
ZB2	M	Etosha NP	Zambezi	18 September 2011	Jan. 9, 2012	113	30	Died January 2012
OJ1	F	Grootfontein area	Otjozondjupa	12 August 2012	Feb. 7, 2013	180	10	Signal failure
OJ2	F	Grootfontein area	Otjozondjupa	12 August 2012	Dec. 21, 2012	132	10	Signal failure
SK1	F	Kamanjab area	South Kunene	29 September 2011	Oct. 12, 2012	380	50	Signal failure
SK2	F	Kamanjab area	South Kunene	2 September 2011	May 4, 2013	611	50	Signal failure

**Fig 1** Map of northern Namibia. The points denote the fixes for the two giraffes released within each region. The labels (a) and (b) denote the approximate locations of Kamanjab and Grootfontein capture areas, respectively

giraffes were translocated from private game farms and national parks into communal conservancies to augment wildlife numbers and ranges, and to support wildlife tourism (Guillemin, 2012). A subset of these animals were fitted with (GPS) collars by personnel of the Namibian Ministry of Environment and Tourism (MET). These collars collected data on the animals' post-translocation movements. In this study, we analysed these data to examine post-translocation movement and home range behaviour to evaluate successful establishment in the release area (*sensu* Armstrong & Seddon, 2008).

Materials and methods

Study area

Translocations were coordinated by the MET and the Millennium Challenge Account–Namibia. The authors of this paper were not involved in the design or implementation of the translocations. Six individuals were fitted with GPS satellite collars (African Wildlife Tracking, Pretoria, South Africa). These collars are currently the only available model of satellite collar being used on giraffes.

Four collars were deployed during translocations in 2011 and two in 2012. Based on relative size and condition, all collared individuals were deemed to be young to prime-aged adults, approximately four to six years old. Five of the six were females.

All giraffes were captured within Etosha National Park or on nearby private land (Table 1) in the Grootfontein and Kamanjab areas, and were translocated to three sites across northern Namibia (Fig. 1; Table 1). Animals were mass captured in bomas by helicopter and transported to the recipient sites within hours by truck. Two collared giraffes were hard-released into each of the three regions. Capture and release sites were matched to minimize the distances between them (Table 1). Etosha National Park (Fig. 1) is characterized by a mosaic of desert, semi-desert and savannah, and receives 400–450 mm of annual rainfall (Curtis & Mannheimer, 2005). The Grootfontein area (Fig. 1) receives 500–550 mm of annual rainfall and is characterized by northeastern Kalahari woodland (Curtis & Mannheimer, 2005). The Kamanjab area (Fig. 1) is largely mopane savannah and receives 300–350 mm of annual rainfall (Curtis & Mannheimer, 2005). The Zambezi Region (ZB; Fig. 1) is characterized by a mosaic of woodland savannah and receives 500–700 mm of annual rainfall (Godenschweig, 2012). The South Kunene Region (SK) is predominantly arid desert plains (50–300 mm annual rainfall) with ephemeral rivers supporting *Acacia*-dominated riparian zones (Godenschweig, 2012). The Otjozondjupa Region (OJ) is largely semi-arid sandy plains and dunes characterized by *Combretum* and *Acacia* savannahs with 380–480 mm of annual rainfall (Strohbach *et al.*, 2004). At the time of release, there were no resident giraffes in the Zambezi and South Kunene Regions and fewer than 0.01 giraffes km⁻² in Otjozondjupa (J. Fennessy, pers. obs.). The density of predators, in particular lions, in all three regions was very low at <0.01 km⁻² (Moeller, 2014). Approximate distances between capture and release sites were 130 km for South Kunene, 790 km for Zambezi and 260 km for Otjozondjupa.

Duration of data collection varied among individuals due to animal death, battery exhaustion and other collar failure; fixes were obtained by GPS satellite download (Table 1). The number of fixes per individual per day ranged from one to 24. We resampled the data to the minimum frequency of one fix per day. For each individual, we chose one fix among the multiple fixes per day so the period between sequential fixes remained as close to 24 h as possible. We calculated movement distances

(distance between two sequential fixes) and movement angles (bearing of the line connecting two sequential fixes), using Geospatial Modeling Environment (Beyer, 2012). We inspected movement distances for unrealistic values that would suggest GPS location errors and found none. Furthermore, we inspected HDOP values for each fix, and these were low [mean (SD) = 1.18 (1.82)], indicating favourable satellite geometry.

Home range size

We used two methods to estimate home range size and intensity of space use: the 95% MCP and the adaptive local convex hull (a-LoCoH). Because of its simplicity, MCP is widely used for describing space use but is criticized for its susceptibility to outliers and coarse representation of space use (Laver & Kelly, 2008). We employed MCP to facilitate comparisons with historical estimates.

In examining the intensity of space use, we used a-LoCoH, a nonparametric kernel method to estimate utilization distributions (Getz *et al.*, 2007). With this technique, a local convex polygon is created around each coordinate fix using a variable number of surrounding points, the sum of whose distances from the focal point is less than or equal to the parameter *a*. The parameter *a* was set for each individual giraffe as the maximum distance between any two coordinate fixes (c.f. Coleman & Hill, 2014; Getz *et al.*, 2007). The individual polygons are ranked by size from smallest to largest, and the area comprised of the overlapping of polygons formed by *x*% of focal points constitutes the *x*% isopleth (Getz *et al.*, 2007). The a-LoCoH method is particularly robust to hard boundaries; we selected a-LoCoH over other techniques (e.g. kernel density, Brownian bridge) as there were instances of hard borders (fencing) at the perimeter of some conservancies (Getz *et al.*, 2007; Lichti & Swihart, 2011). Following commonly used boundary thresholds, we used the 95% isopleth to characterize total home range and the 50% isopleth to define the core range (Getz *et al.*, 2007; Hensman *et al.*, 2013).

Home range behaviour

We used several methods to assess the degree to which movement behaviour of individual giraffes suggested home range establishment. Munger (1984) points out that home range movement deviates from random movement by establishing site fidelity to some region of

space. Thus, we expected several distinct movement patterns to emerge from site fidelity. The first is that the cumulative area of habitat used should plateau over time. We assessed this by inspecting plots of the cumulative proportion of the final 100% MCP home range versus days elapsed since tracking commenced. The second is that movement angles should be biased towards the centroid of all fixes. We used the localizing tendency model of Moorcroft & Lewis (2006) to compare the relative amount of bias among individuals. This method uses the fixes and movement directions to estimate the parameters of a von Mises distribution. The estimated concentration parameter, \hat{k} , reflects the magnitude of movement bias. \hat{k} of zero represents unbiased movement,

and higher values represent an increasing concentration of movement angles towards the centroid.

We also employed the Monte Carlo bootstrap method of Danielson & Swihart (1987) to evaluate site fidelity; observed movement distances are paired with random movement angles to simulate movement without site fidelity. The number of simulated fixes was the same as the number of observed fixes for each giraffe, and these were used to calculate 95% MCP. This was repeated 100 times for each animal. If individuals exhibit site fidelity, the expectation is that observed home ranges should be smaller than simulated home ranges. To determine statistical significance, each giraffe's observed 95% MCP size was compared to the 95th percentiles of the simulated MCPs.

Table 2 Minimum convex polygon (MCP) and adaptive local convex hull (a-LoCoH) home range estimates, in km²

	ZB1	ZB2	OJ1	OJ2	SK1	SK2
100% MCP	76.9	112.3	11,691.8	5121.0	859.2	1973.9
95% MCP	66.3	60.6	9565.2	4928.2	751.3	776.0
50% MCP	31.6	13.0	2582.3	3599.0	167.1	135.9
100% a-LoCoH	65.6	32.6	3971.0	1164.2	432.2	1273.1
95% a-LoCoH	47.1	30.3	2960.7	634.6	233.6	483.4
50% a-LoCoH	5.0	6.9	266.2	267.2	46.6	86.3

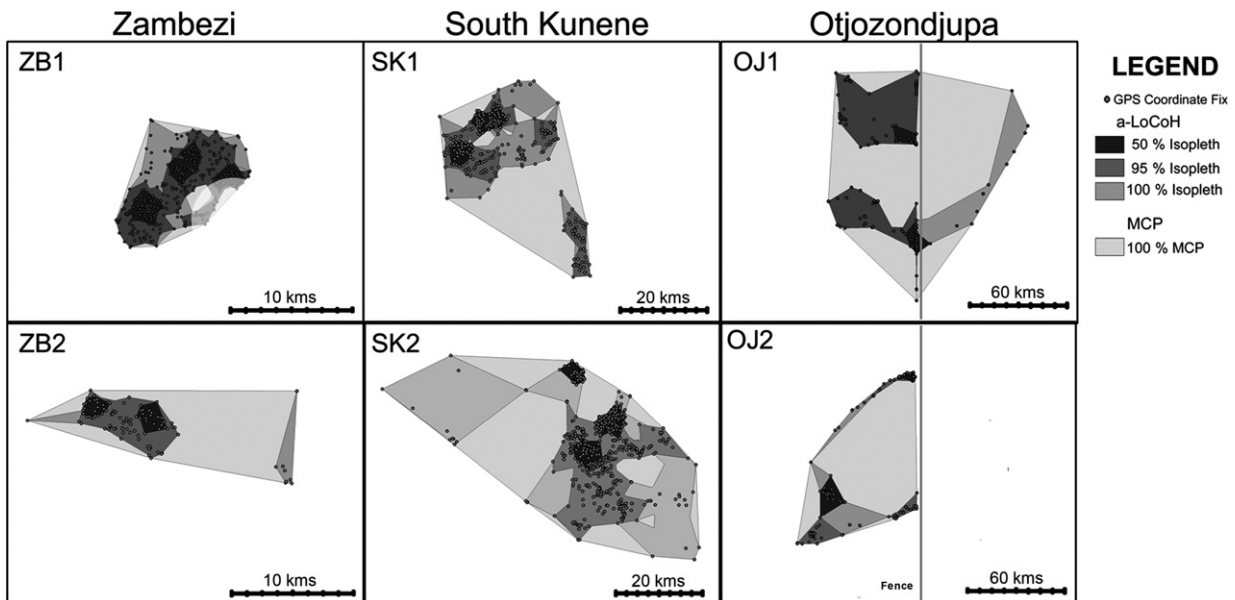


Fig 2 Home ranges and utilization distributions for each giraffe as estimated by MCP and a-LoCoH techniques. The vertical lines in the Otjozondjupa giraffes' panels represent the Namibia-Botswana border fence

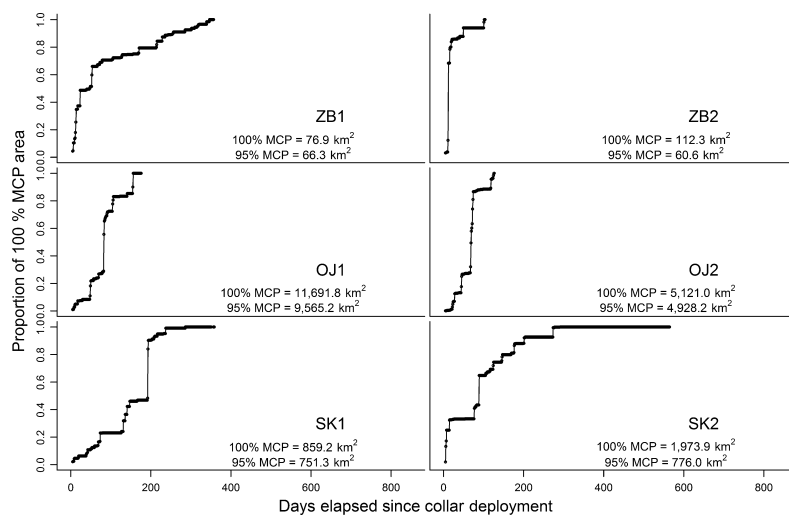


Fig 3 The cumulative 100% minimum convex polygon (MCP) estimates for the focal giraffes as a proportion of the maximum home range estimate for each giraffe, plotted against the days elapsed since the start date. We used 100% MCP for these figures so that the curves were uniformly increasing. As 95% MCP is a statistical estimate, the estimated home range sometimes gets smaller as additional points are added, making interpretation more difficult

To facilitate comparison among individuals, we calculated the 95% MCP, the Monte Carlo bootstrap and the localizing tendency model on both the full data for each individual and on data truncated at the smallest data record size of 113 days.

Results

Home range size and structure

Home range sizes varied among individuals by a factor of 100 for MCP and a-LoCoH estimates (Table 2), and those from the individuals translocated to the Otjozondjupa Region were much larger than previous estimates for giraffes across Africa (Table S1). The previous largest home range size observed was 1773 km² for a desert-dwelling Angolan giraffe in Namibia, but the 95% MCP estimates for OJ1 and OJ2 were more than double that value (Table 2; Table S1). The rank order of individual home range sizes was preserved after truncating the data to the minimum record size.

As expected, the a-LoCoH estimates of home range size were smaller than the MCP estimates (Table 2). Utilization distributions from a-LoCoH showed uneven space use over the extent of the home ranges (Fig. 2). The 50% isopleth on average encompassed only 25% of total home range area, suggesting most focal giraffes restricted the majority of movements to core areas within the home ranges with occasional long-distance movement between core areas.

A north–south fence on the Namibia–Botswana border affected OJ1 and OJ2’s movement (Fig. 2). OJ1 moved along the Namibia side extensively before crossing through and

making a long, rapid foray into Botswana. It then moved along the fence in Botswana before crossing back into Namibia. Movement by OJ2 was impeded by the fence twice.

Home range establishment

The interpretation of individuals’ space use over time is complicated somewhat by the differing durations of data collection (Fig. 3; Table 1); however, some patterns are evident. Use of new space by the three giraffes with longer data records (ZB1, SK1, SK2) tended to slow or cease. The comparatively shorter period of data collection for ZB2, OJ1 and OJ2 makes it difficult to draw inferences about the temporal pattern of exploratory behaviour.

The localizing tendency model also revealed different levels of movement bias among giraffes towards home range centres. ZB1, ZB2, and SK1 had the most biased movement towards the centres of their home ranges, based on \hat{k} values (Table 3). OJ2 and SK2’s biases were intermediate, and OJ1 had the least biased movement towards the home range centre. The pattern of \hat{k} values was similar using both the full and truncated data sets.

The Monte Carlo bootstrap analysis provided statistical support for the assertion that movement behaviour deviated from random expectations. ZB1, ZB2, SK1 and SK2 had negative Z-scores and, using the full data sets, their observed MCP sizes fell beyond or near the lower 95th percentile of the expected MCP sizes, indicating they exhibited significantly smaller home range sizes than expected based on random movement angles (Table 3; Fig. S1). OJ1 and OJ2 had positive Z-scores, and their observed 95% MCP sizes were close to the upper 95th

Table 3 Results of the Monte Carlo bootstrap analysis and localizing tendency model. We compared the observed 95% MCP home range estimates (km^2) to the expected 95% MCP values based on simulated random walks. We also truncated each collar data set to the duration of the shortest data set (113 days) and re-analysed to compare the results across similar time frames (SD = standard deviation)

	ZB1		ZB2		OJ1		OJ2		SK1		SK2	
	Full	Truncated	Full	Truncated	Full	Truncated	Full	Truncated	Full	Truncated	Full	Truncated
Mean expected 95% MCP	534.3	184.9	358.0	358.0	6585.0	4285.9	2877.6	1668.3	1905.4	267.3	3608.8	1087.5
Expected 95% MCP SD	192.1	76.0	203.6	203.6	3206.3	1876.0	1314.3	799.6	745.0	113.8	1365.6	531.5
Observed 95% MCP size	66.3	48.2	60.6	60.6	9565.2	8097.9	4928.2	4475.1	751.3	167.3	776.0	831.7
Z-score	-2.44	-1.80	-1.46	-1.46	0.93	2.03	1.56	3.51	-1.55	-0.88	-2.07	-0.48
Percentile	99.3	96.4	92.8	92.8	82.4	97.9	94.1	99.9	93.9	81.0	98.1	68.5
\hat{k}	1.23	1.26	1.77	1.77	0.47	0.48	0.88	0.85	1.19	1.31	0.87	0.85

percentile, suggesting their movements were more linear than expected (Table 3). These results were qualitatively similar whether full or truncated data sets were used, although percentile values were smaller for SK1 and SK2 with the truncated data sets.

Discussion

The metrics we applied to the post-translocation GPS collar data revealed divergent space use patterns among the six translocated giraffes. They suggested a comparatively stable use of space by the four giraffes translocated to the Zambezi and South Kunene Regions, consistent with the establishment of home ranges. In contrast, two individuals translocated to the Otjozondjupa Region did not appear to establish home ranges.

Movements of three of the four Zambezi and South Kunene giraffes (ZB1, ZB2 and SK1) showed relatively strong bias towards the centroid of their fixes, indicating they oriented to remain within a circumscribed area (Table 3). Based on full data sets, all four Zambezi and South Kunene giraffes had significantly (or nearly so – 93rd to 99th percentiles) smaller home range sizes than expected (Table 3). Also, SK1 and SK2 ceased exploratory movements by 60% of the way through their observation periods, and ZB1 slowed its explorations (Fig. 3).

The giraffes translocated to the Otjozondjupa Region exhibited notably different movement behaviour and did not appear to establish stable home ranges. They both exhibited long-distance near-linear movement (Fig. 2; Fig. 3), which, despite a comparatively shorter period of data collection, produced exceptionally large home range estimates that were much larger than expected based on random walks (Table 3). They also showed relatively weak bias towards the centres of their putative home ranges (Table 3).

The a-LoCoH home range estimates suggested that for five of the six individuals, utilization was concentrated in a relatively small portion of the total home range (Table 2). Additionally, a-LoCoH correctly handled known movement barriers, truncating OJ1 and OJ2's home ranges at the Namibia–Botswana fence.

The estimates for the Otjozondjupa individuals represent the largest published giraffe home ranges to date (Table S1). The 95% MCP estimates for OJ1 and OJ2 were over twice as large as the largest home range size previously observed (Table 2; Table S1). Even using the more conservative 95% a-LoCoH estimates, OJ1 still had a larger home range than any previously published.

However, our other analyses suggest it may not be appropriate to consider these to be home ranges; thus, these comparisons need to be made cautiously. The unprecedentedly large size of these estimated home ranges further supports our conclusion that these giraffes were not displaying typical home range movement behaviour.

The giraffes in the South Kunene and Zambezi Regions exhibited home range sizes more comparable with those in the literature. The Zambezi giraffes exhibited the smallest home ranges of the focal giraffes, which could be explained by the region's productivity, as the Zambezi Region receives the most rainfall of the three regions. It also has the highest human population density, which could constrain giraffe space use, but inspection of satellite imagery did not reveal obvious land use changes at home range boundaries. Although the South Kunene Region was the most arid of the three regions, the South Kunene giraffes did not exhibit home ranges larger than those of the Otjozondjupa giraffes. The distribution of resources in these two regions may explain the discrepancy. The South Kunene release area contains seasonal drainages that support abundant browse along which giraffes forage (Fennessy, 2009). The Otjozondjupa release area is characterized by significant bush encroachment and lacks well-developed drainages.

Our results support that the four collared giraffes translocated to the South Kunene and Zambezi Regions became successfully established in the release areas. The movement behaviour of these animals appears consistent with the establishment of home ranges. To more fully judge the outcome of these translocations, that is to assess whether a self-sustaining population had been established, would require longer-term demographic data (Pierre, 1999; Fischer & Lindenmayer, 2000).

The movement data from the Otjozondjupa Region raise concerns about the successful establishment of those individuals. The wide-ranging linear movements suggest exploratory behaviour that may reflect poor habitat suitability. This could be due to the distribution and abundance of browse and/or water, as well as the presence or absence of conspecifics, human disturbance and predators. The lack of any pretranslocation data on these individuals or any spatial data on food and water resources at a relevant spatial scale precludes any stronger inferences about the causes of these movement patterns.

Additionally, the lack of any previous studies of giraffe movement in the Otjozondjupa Region precludes us from definitively ruling out that the behaviour observed is typical giraffe home range behaviour in that environment.

However, in comparing these individuals to what is known about giraffe home range behaviour (e.g. Table S1), we find this scenario unlikely. An alternative explanation is that some aspect of the handling of these animals during the translocation process inspired this movement behaviour. In our opinion, further follow-up on past translocations to this region should be carried out before additional translocations are considered.

Given the increasing use of translocation, it is important for conservation managers to employ rigorous monitoring techniques to assess the success of conservation translocations and to learn how to perform them more effectively (Ewen, Soorae & Canessa, 2014). Our results suggest that monitoring the movements of animals following translocation can provide an early indication of translocation success and can allow for early detection and mitigation of problems. While this case study illustrates the utility of movement data in data-poor translocation efforts, it also points out the many limitations imposed by the lack of additional data. Additional pre- and post-translocation data on individuals and the environment would have allowed for more definitive evaluation and diagnosis of problems. We support the IUCN guidelines and encourage entities involved in wildlife translocation to develop their abilities to carry out the pre- and post-translocation measures advocated in the guidelines through internal capacity development and by partnering with government, academic and nonprofit organizations as appropriate.

Acknowledgements

We would like to thank Jonathan Chipman and Nina Lany for assistance with spatial analyses, the MET and particularly Pierre du Preez for access to the data, and Vincent Guillemin of the Millennium Challenge Account–Namibia for his efforts and input.

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(Manuscript accepted 14 January 2016)

doi: 10.1111/aje.12299

Supporting information

Additional Supporting Information may be found in the online version of this article:

Table S1 Giraffe home range sizes (km²) from the literature.

Figure S1 Illustrative results of Monte Carlo bootstrap analysis for two focal giraffes.