Application of ArcView Animal Movement Analysis Extension as a tool for monitoring elephant movement: preliminary results from northern Cameroon

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Abstract

ArcView Animal Movement Analysis Extension was used to survey the movement of two female elephants, Eka from Benoué National Park and Habsatu from Bouba Ndjida National Park in northern Cameroon. The results show that Eka is seldom in the park if 5% of the outliers are not considered, while Habsatu is in the park more often, especially in its northern and western parts, and she moves over the border into Chad. Home ranges were calculated as 1750 km^2 for Eka and 2058 km^2 for Habsatu. Recommendations are made for improving the study in the future.

Résumé

L'Extension ArcView Analyse du Mouvement Animal a été utilisé pour étudier le mouvement de deux éléphants femelles, Eka et Habsatu respectivement des parcs nationaux de la Bénoué et de Bouba Ndjida au nord Cameroun. Les résultats montrent que, Eka est difficilement dans le parc lorsque 5 % des points externes sont retirés alors que Habsatu est très souvent dans le parc et plus précisément dans les portions nord et ouest du parc, et se déplace vers la frontière à l'intérieur du Tchad. Les domaines vitaux étaient calculés comme étant de 1750 km^2 pour Eka et de 2058 km^2 pour Habsatu. La discussion est donnée suivi des recommandations pour améliorer l'étude dans le future.

Introduction

Investigating patterns of movement in wildlife species touches upon migration and habitat seletion and informs the design of protected areas. The Elephants of Cameroon is a joint project ot the North Carolina Zoological Park and WWF Cameroon that is studying elephant movement. Its purpose is to monitor the movements of individual African elephants (*Loxodonta africana*) to help determine the areas that they frequent, their migration patterns and habitat requirements. This work is particularly important because of the increasing conflict in Cameroon, as elsewhere in Africa, between elephants and human settlements. The aim of the project is to help develop management plans, such as sustainable land-use policies, and highlight areas requiring protection. This will help to eliminate or at least minimize the destructive interactions that are taking place between elephants and people. In the long term this will help develop sustainable uses of Cameroon's remaining elephant habitats while also providing economic security for local people.

Data used for this project were from two of the elephants being satellite tracked. These data were analysed using ArcView's Animal Movement Analysis Extension (AMAE) version v2.04 beta. As we had not previously used this extension, it was decided to keep the analysis of the data simple, applying the functions available and seeing how useful the outputs would be for environmental management of this nature.

The two elephants chosen for analysis are both adult cows with young calves. Habsatu is part of a herd of 25 elephants whose home range is in Bouba Ndjida National Park; Eka belongs to a herd that congregates around Benoué National Park of northern Cameroon. Both parks are in the Mayo-Rey region of Cameroon and suffer from agricultural encroachment and poaching. Both of these elephants were fitted with Argos satellite collars and radio transmitters.

As AMAE is a recent development there has to date been little in the literature about its usefulness and application. There are, however, projects where some of the functions available within AMAE are being used to analyse information on animal movements from satellite recordings. One such project is based in Malaysia (www.si.eduJelephantl) where conflicts are arising between Asian elephants (*Elephas maximus*) and humans. The problem here is that elephants that have developed a preference for plantation crops rather than natural forest vegetation are destroying plantations (Stüwe et al. 1998).

In this project elephants are being tracked by satellite and the resulting data analysed using GIS. The purpose is to determine the effects of translocating elephants, whether they establish a new home range, the consequences of moving individual female elephants separated from their matriarchal herd, and whether translocated elephants remain within the boundaries of nature reserves or choose to seek out plantations (Stüwe et al. 1998).

GIS is also being used to track animal movements in the aquatic environment. The people responsible for the Malaysian elephant-tracking project are also running a project named Ocean Ambassadors. One aspect is tracking green turtles (*Chelonia mydas*) using satellite telemetry. GIS is being used to monitor turtle movements, migration paths and the impact that anthropogenic activities such as trawling and the use of long lines are having on them.

In northern Cameroon, Tchamba et al. (1995) used satellite telemetry to track elephant cows in Waza National Park. The study found that one elephant mainly used the central and north-western parts of the park and migrated 80 km north in the dry season; the other elephant used the south-eastern parts of the park and migrated 100 km south in the wet season (Tchamba et al. 1995). The study also used the minimum convex polygon (MCP) method to determine home ranges. Another study by Verlinden and Gavor (1998) satellite-tracked elephants in northern Botswana. GIS was used to relate positions to spatial factors such as water distribution and vegetation types. They found that home range size increased with an increased distance to dry-season surface water. Migratory herds were also observed to move between fixed wet- and dry-season ranges (Verlinden and Gavor 1998).

Methods

Data required

1) Maps of Cameroon, Chad and the national parks that the elephants use. 2) Field data—the date, time, latitude and longitude of elephant positions. 3) Field data—vegetation cover for the area under study.

Sources of data

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Digitized maps of Cameroon and Chad were obtained from the US Geological Survey West Africa Spatial Analyst Project, http://edcintl.cr.usgs.gov/adds/adds.html. Metadata for these maps were available at the following site: http://edcintl.cr.usgs.gov/adds/c1In/cmldoc/wasa!cmwasa.html. The maps of Benoué and Bouba Ndjida National Parks were obtained from the Elephants of Cameroon website (2000). These maps were not digitized and metadata were not available.

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Elephants were collared as described by Tchamba et al. (1995). The date, time, longitude and latitude of the elephant's positions were obtained from the Elephants of Cameroon website (2000). There was concern about the accuracy of the data available on the Internet, the positions provided by the satellite and also why each data set was not complete. To clarify these issues the project was contacted via email (fran.nolanncmail.net). We were informed that the satellite data were correct and that data sets for individual elephants were not complete up to the present because the satellite collars had failed. Vegetation data were omitted from the project as there were problems opening the files in ArcView. Inclusion of these data and a digital elevation model of the area would have made the project more realistic. It would have enabled the true attributes of the area and the diversity of habitats to be portrayed. This would allow analysis of preferred habitats to be undertaken and areas of potential conflict to be determined.

Input and processing methods

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Data sets for Eka and Habsatu consisting of date, time, latitude and longitude were copied from the Elephants of Cameroon website (2000) and pasted into the computer package Excel. Data were separated into four columns and formatted to be meaningful when imported into ArcView. Once these individual tables were completed, each was saved as a dBase 4 file, which allowed the ArcView project to open them.

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Files containing data on Cameroon and Chad were downloaded from the West African Spatial Analysis Project website (2000). The files consisted of projects, rather than simply maps. Consequently, before they could be imported into ArcView they first had to be imported into ERDAS Imagine version 8.1. Here they were converted to Arc/Info files using the Arc Interchange to Arc Coverage option. This conversion made it possible to import them into ArcView.

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Maps of the parks were saved onto disk from the Elephants of Cameroon website (2000) as jpeg files. They were then imported into ERDAS and converted so that they could be exported to ArcView as a grid data source.

Each map then had to be georeferenced so that the national parks, road and rivers could be digitized and placed onto the map of Cameroon. To do this, 25 ground control points were chosen and listed in an Excel spreadsheet, which was then saved as a dBase 4 file. These were points of uncertainty retained on the map during satellite image analyis. The points were manually introduced into a GPS Gamin 12 XL and divided into reference zones from which data were verified in the field wih the help of local guides.

The map of the national park area was created as an event theme to which this table was added. The projection of the view was changed to UTM 1983, Zone 33, and the selected ground control points were then added to the view using the add event theme. The add x, y, coordinates function under the Movement menu was then used to add the latitude and longitude coordinates to the attribute table. This table was then exported as a dBase 4 file to Excel where it was printed out and the image geocorrected in ERDAS following the method of Winterbottom (2000).

The geocorrected map could then be imported into ArcView and overlaid on the digitized Cameroon map. This made it possible to digitize the rivers, roads and national park areas and add them to the view as a new theme.

Once the national parks were entered into the view, the map showing the area under study was complete. The positions of the elephants were then added to the project.

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The MCP method of calculating home range is greatly affected by outliers. Removing 5% of the outliers can mitigate this effect. Therefore, to analyse the positions of the elephants, obvious outliers first had to be removed. This was carried out on both Eka's and Habsatu's positions. The outlier removal function under the Movement menu was used to remove 5% of the data points. The outlier removal function works by the harmonic mean method, which is quite a slow procedure, particularly when the data set is large, as for Habsatu. ArcView displays these points in two colours—one showing the points that have been excluded and another showing the points retained, which can then be used for further analysis. These points were converted to a shape file from which the 5% of outliers were excluded to allow further analysis to be conducted.

Results

Habsatu's positions provided 386 data sets covering a 522-day period from 27 May 1998 to 31 October 1999. Eka's positions consisted of 84 data sets covering 111 days between 27 February and 18 June 1999 inclusive.

Use of national parks

A display of Eka's positions shows that she is hardly ever in the park. When 5% of the outliers have been

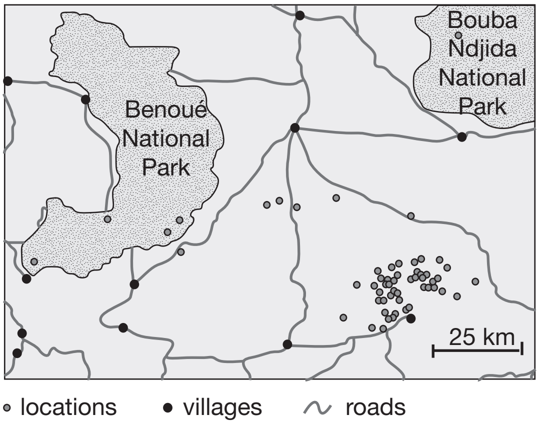

Figure 1. Eka's locations in Benoué National Park.

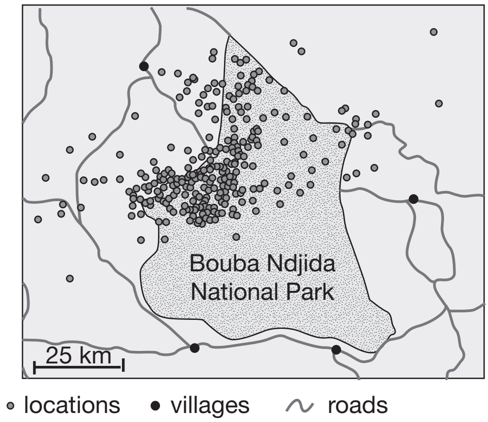

Figure 2. Habsatu's locations in Bouba Ndjida National Park.

removed, she is not in the park at all (fig. 1). Figure 2 shows that Habsatu is in the park more often, especially in its northern and western parts. She also moves over the border into Chad, where elephants are at risk from poachers. If vegetation had been mapped it would be possible to propose hypotheses about habitat preferences in relation to the elephant's positions.

Home range analysis

Many studies concerned with animal movement are interested in determining the home range. Four different methods of home range calculation are available within AMAE: Kernel, MCP, Jennrich-Turner and Harmonic Mean. The latter two methods of calculation were not used in this study. The Jennrich-Turner home range, while having the advantages of speed and simplicity, assumes the data follow a bivariate normal distribution, a requirement that animals in the wild often do not meet. This method is principally useful for generating the principal axis of the data. The Harmonic Mean home range is especially useful in determining animal activity centres. AMAE does not calculate area values for the Harmonic Mean home range. We have chosen to implement the first two models, based on their robustness and common usage.Results of using the other methods are as follows.

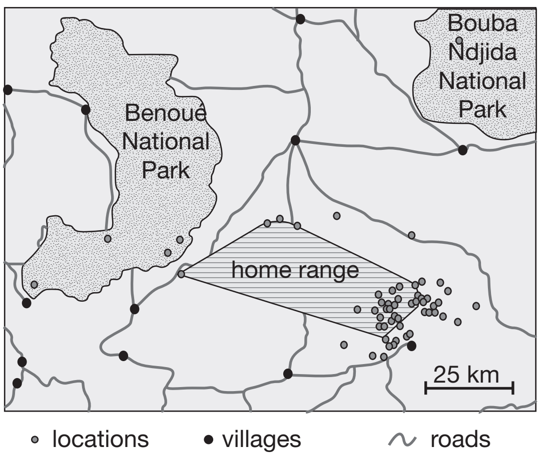

Figure 3. Eka's home range calculated using MCP.

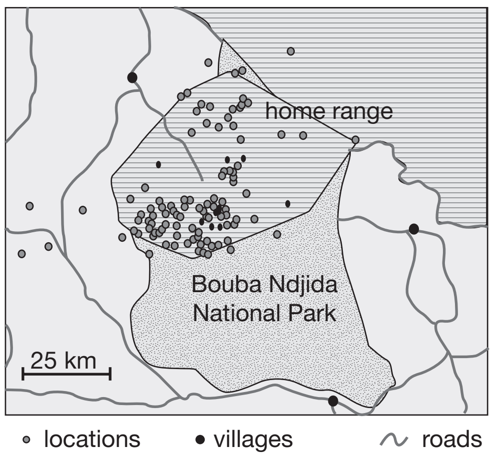

Figure 4. Habsatu's home range calculated using MCP.

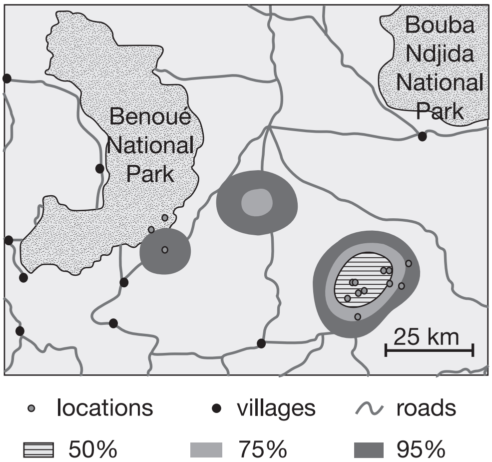

Figure 5. Eka's Kernel home range.

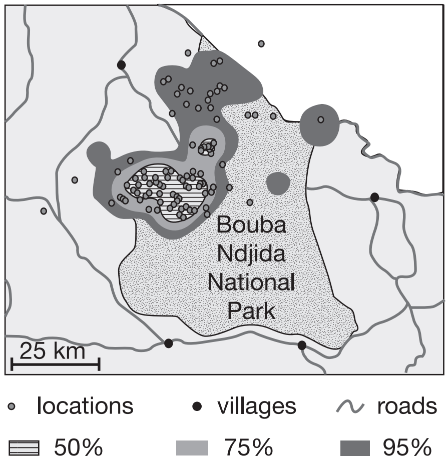

Figure 6. Habsatu's Kernel home range.

Eka's home range calculated using MCP was 1749.698 km² and Habsatu's 2057.72 km² (figs. 3, 4). With the probabilistic Kernel method, Eka's home range was calculated using a 95% probability polygon and Habsatu's using a 50% one (figs. 5, 6).

Wet- and dry-season positions for Habsatu

The query function was used to determine Habsatu's position in wet and dry seasons (figs. 7, 8). The different methods of calculating home range can then be run with this reduction of data and the results compared with the home range for the data set as a whole.

The ability to do this is extremely useful as it enables managers to identify seasonal patterns of movement and therefore seasonal migration routes and seasonal home ranges. This information can be used to develop management plans. If vegetation and human populion data or information on distance to water could also be used, reasons for the range covered in respective seasons would become clearer by drawing up correlation analysis.

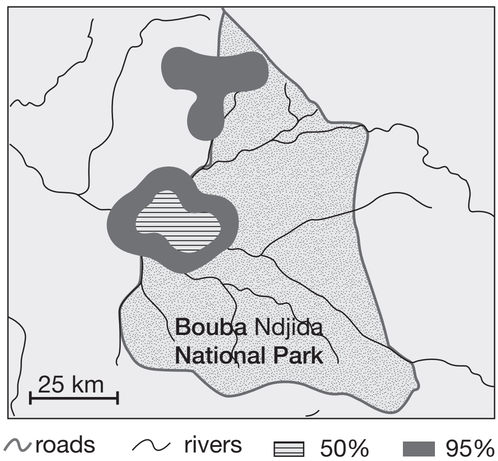

Figure 7. Habsatu's dry-season Kernel home range position.

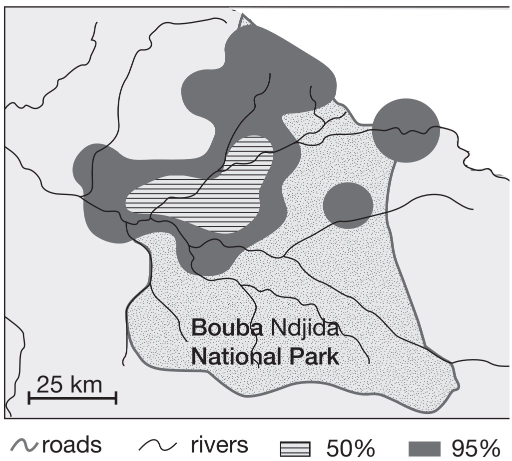

Figure 8. Habsatu's wet-season Kernel home range position.

Table 1. Statistics on Eka's and Habsatu's positions

Item	Eka[a]	Habsatu[b]
Sample size	80	25
Minimum distance	247 m	247 m
Maximum distance	38,990 m	22,587 m
Total distance	625,010 m	140,172 m
Mean distance	7,912 m	5,841 m
Minimum date	27 Feb 99	—
Maximum date	18 June 99	—
Duration of study	111 days	24 days
Minimum speed (units/day)	—	663 m
Maximum speed (units/day)	57,521 m	22,587 m
Mean daily speed	5,633 m	6,094 m
MCP area	1,750 km²	2,058 km²

[a] 5% of outliers removed
[b] positions 2–25 July 1999

Statistics on elephant positions

AMAE has the facility to calculate location statistics on the active point theme using either all the data sets or a selection. A selection of the descriptive statistics generated is illustrated in table 1.

The statistics function is especially useful when used in conjunction with a query. Queries can be run on an active point theme to determine, for example, how far an elephant has moved within a certain amount of time. The results of such an analysis are shown in table 1.

The statistical capabilities within AMAE are currently limited although there is an option to export data to stand-alone statistical applications such as SPSS for further analysis.

Discussion

The MCP method of calculating home range is one of the most widely used (White and Garrot 1990; Kenward 1992; Hooge et al. 1999). The method shows the area the animal uses and traverses. Its major fault is that it is sensitive to sample size. As the total area is being calculated the size of the home range can increase indefinitely as new locations arise outside of MCP (White and Garrot 1990). It is therefore affected by outliers and the animal may never use much of the area contained within the polygon (Hooge et al. 1999). To reduce this effect MCP was calculated for both Eka and Habsatu once 5% outliers had been removed. The area of home range calculated using the Kernel method is a more realistic interpretation of what an animal is likely to use than the area calculated under the MCP method.

In this study accuracy concerns were based on whether the satellite recordings were correct. One of Habsatu's positions was so far away from her other positions (fig. 2) that it would appear that 13 degrees longitude were recorded instead of 14 degrees longitude. This could be data entry error or an incorrect spatial reference from Argos. Duplicate entries were also found on a couple of occasions. These factors make the quality of the data questionable.

One problem of using Argos satellite telemetry is the low accuracy of individual locations and the low resolution. These factors prevent detailed analysis of animal locations (Stüwe et al. 1998). Low accuracy ratings may occur if the satellite does not receive sufficient signals from the collar (Stüwe et al. 1998). This is a particular problem near the equator, where opportunities are short for a location to be taken as the satellite passes. It is therefore questionable how accurate the data used in this study were on elephant positions. However, accuracy of the GPS devices could be tested both before and after they are deployed.

From what has been determined in the findings it can be seen that AMAE, despite a few shortcomings such as slow processing of large data sets, is a useful package for analysing animal movements. More could have been obtained from this study if vegetation data and elevation data had been incorporated. Increased knowledge and experience of using the extension would also have improved the analysis.

In light of the findings the following recommendations are put forward to improve this study for use in the future.

- Although there are a lot of data points for each elephant, the sample size is only two. Consequently, for valid scientific conclusions to be drawn, more individual elephants in the herds to which Eka and Habsatu belong need to be collared and tracked by satellite.
- Adult bull elephants are known to cause considerable damage to crops and villages in other parts

of Africa (Hoare 1999). Collars should therefore also be fitted to adult bull elephants, to establish the level of damage and disturbance to human settlements that they cause.
- To make this study more realistic and to enable further analysis of, for example, home ranges in relation to preferred vegetation and migration routes in correspondence with food supply, vegetation and elevation data need to be incorporated.
- GPS collars should be fitted. This would enable real-time collection of data from a GPS using ESRI's Tracking Analyst Extension and AMAE. This would increase the accuracy and therefore improve the analysis.
- The distance function should be used to determine the areas moved from the national parks and the rivers.
- The error of the satellite positions could be checked by using radio-tracking methods to locate the elephants and compare positions on the ground with those provided by the satellite.
- The use of a statistical package such as SPSS version 10.01 for Windows should be used to test whether hypotheses are relevant.

Acknowledgements

Financial support from the North Carolina Zoo is gratefully acknowledged. Special thanks go to the WWF Cameroon Country Programme Office for the logistics. We appreciate very much the collaboration of Dr Donfack Paul and our field assistants, Sylvain Tyawoun and Yello Yves, during the fieldwork. The research was carried out under a permit from the former Cameroon Ministry of Environment and Forestry.

References

Elephants of Cameroon. 2000. Saving Africa's vanishing giants, The Elephants of Cameroon. http://www.nczooeletrack.org/project/index.htm. Accessed 25 February 2000.

Hoare RE. 1999. Determinants of human–elephant conflict in a land-use mosaic. *Journal of Applied Ecology* 36: 689–700.

Hooge PN, Eichenlaub WM, Solomon EK. 1999. Using GIS to analyse animal movements in the marine environment. USGS, http://www.absc.usgs.gov/glba/gistools/index.html.

Kenward RE. 1992. Quantity versus quality: programme collection and analysis of radio tracking data. In: Priede IG, Swift SM, eds. *Wildlife telemetry, remote monitoring and tracking of animals*. Ellis Horwood Limited, Chichester.

Stüwe M, Abdul JB, Nor BM, Weminer CM. 1998. Tracking the movements of translocated elephants in Malaysia using satellite telemetry. *Oryx* 32(1):68–74.

Tchamba MN, Bauer H, De longh HH. 1995. Application of VHF-radio and satellite telemetry techniques on elephants in northem Cameroon. *African Journal of Ecology* 33(4):335–346.

Verlinden A, Gavor IKN. 1998. Satellite tracking of elephants in northem Botswana. *African Journal of Ecology* 36(2):105–116.

White GC, Garrot RA. 1990. *Analysis of wildlife radio-tracking data*. Academic Press, San Diego.

Winterbottom S. 2000. *Geographic information systems and remote sensing: course workbook*. University of Stirling, Stirling, Scotland, UK.