The use of the Global Positioning System for real-time data collecting during ecological aerial surveys in the Kruger National Park, South Africa

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The use of the Global Positioning System (GPS) for real-time data collecting during ecological aerial surveys (EAS) in the Kruger National Park (KNP) was investigated as an alternative to post-survey manual data capture. Results obtained during an aerial census of large herbivores and surface water distribution in the northern part of the KNP using an onboard GPS connected to a palmtop computer are discussed. This relatively inexpensive system proved to be highly efficient for real-time data capture while additional information such as ground velocity and time can be recorded for every data point. Measures of distances between a ground marker and fix points measured during a flight ($\overline{x}$ = 60,0 m) are considered to be well within the requirements of the EAS.

Key words: aerial survey, census technique, data collecting, GPS, Kruger National Park.

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Introduction

Annual ecological aerial surveys (EAS) have been conducted in the Kruger National Park (KNP) since 1977 (Joubert 1983). The overall objective of this long-term monitoring project is to investigate population trends of large herbivores and to relate the trends to changes in environmental conditions.

Approximately 36 400 data entries are recorded during each survey of 66 census blocks during about 250 hours' flying time. The surface area of the KNP census blocks varies between 142,9 km^2 and 538,8 km^2 ($\overline{x}$ = 288,3 km^2). In the past, data points, consisting of surface water and animal occurence as well as the location of survey strips, were recorded on maps using codes. These data points are then entered into a computer using a digitiser tablet and cartesian coordinates. The digitising phase totals an average of about 45 hours per survey involving one or two people. In addition to the time required to capture the data, this phase contributed significantly to data errors due to the difficulty of deciphering handwriting, keyboard and digitising errors.

LORAN-C, a long-range electronic navigational aid has been used during aerial surveys of wildlife (Boer *et al.* 1989). However, LORAN-C does not provide worldwide coverage and its signals could be affected by weather (Anon. 1990). Effective real-time capture of positional data only became possible with the availability of the Global Positioning System (GPS).

Consequently it was decided to investigate a GPS connected to an onboard, palmtop computer for inexpensive, real-time data capture to minimise some of the present system's weaknesses. The GPS is a satellite-based radio navigation system that provides contin-

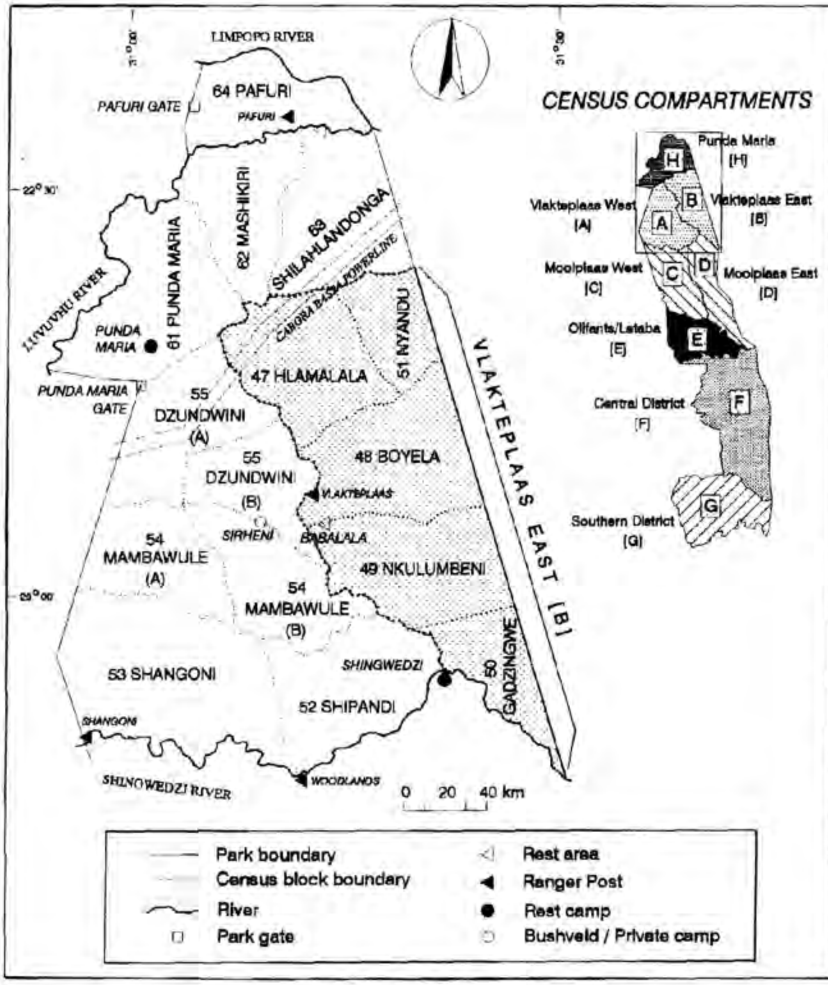

Fig. 1. Census blocks for the Kruger National Park north of the Shingwedzi River.

uous, accurate, three-dimensional positioning worldwide. Several publications describe the functioning of GPS and a variety of GPS applications (Gormley 1990; Petersen 1990; Anon. 1991; Gibbons 1992; Whitehead 1992; Greer 1993; Lance 1993).

During September 1993 a survey of large herbivores and surface water availability had to be conducted in the 1 324,8 km^2 Vlakteplaas East Census Compartment (B) in the northern KNP (Fig. 1). This survey provided an ideal opportunity to test the feasibility of a GPS and palmtop computer for real-time data capture as an alternative to manual data capture using a digitiser tablet.

Material and methods

Various methods for the aerial censusing of large African herbivores has been described by Norton-Griffiths (1978), Collinson (1985) and Bothma (1989), as well as the recording of data either by tape recorder or by writing down (Norton-Griffiths 1978).

The use of a tape recorder is often preferable as every observer can record data individually without looking away from the survey strip. It is also considered to be less time consuming for a multi-species count than writing down (Norton-Griffiths 1978). However, accurate positioning of observations is difficult using a tape recorder. Writing down data on maps was selected as a method for data recording during the EAS rather than using a tape recorder as it was considered important to record the distribution of both animals and water as accurately as possible.

Viljoen (1989) gives a detailed discussion of the general methodology used during the EAS in the KNP. Each census block is systematically surveyed at a height of 65-70 m above ground in parallel strips 800 m wide (400 m on each side of the flight path), flying at about 166-185 km/hr (95-100 knots). A twin-engined, fixed-wing Partenavia Observer is used and the survey team of six consists of a pilot, a data recorder and four observers. The EAS is a multi-species census during which information on variables such as the availability of surface water is also recorded. Numbers of animals are determined by direct counting. However, when large concentrations of impala, elephant and buffalo are encountered, numbers are estimated visually.

A Garmin AVD 100 GPS (Garmin Communication and Navigation, Lenexa, USA) was linked to a Janus J2010 hand-held computer (Intermec, Everett, USA) using a serial communications connection. The GPS downloads a data stream every two seconds which includes positional data (latitude / longitude), time and ground velocity.

A data capture program was developed in C++ (Borland, International, Scotts Valley, USA) to combine keyboard data entries with positional data obtained from the GPS. Each data entry consisted of species, number counted, locality, time and ground velocity of the aircraft. The start and end of each strip (positional data and time) were also recorded (Appendix A). Data capture was to an ASCII file (Appendix A) on a Type I SRAM memory card in the palmtop computer. The data capture program allows for a position to be temporarily "frozen" when large groupings of animals are encountered. Corrections regarding the totals of certain animal groups were recorded using a "comment mode" available in the program to which positional data and time were also added.

The data were transferred after each survey flight through a serial link from the palmtop to a laptop computer. Data editing was done on the laptop using a text processor. SAS (1991) software was used to analyse the data and distribution maps were generated on a computer by means of a spreadsheet and presentation graphics.

Known geographical locations and visual landmarks such as windmills, dams, identifiable large trees and topographical features were used in conjunction with the aircraft's directional indicator (DI) to facilitate navigation. The GPS, however, was also used to assist with navigation between strips, particularly when clear landmarks were occasionally absent.

The accuracy of the GPS under EAS conditions was tested at a road marker, clearly visible from the air, about 5 km south of Skukuza in the KNP. A total of 14 fix points (waypoints), seven per side, were recorded using the GPS and palmtop while flying in opposite directions over the marker and maintaining the air speed and height above ground level (AGL) typically used during the EAS. The exact position of the road marker was later determined using a GPS on the ground.

Results

A total of 200 strips were flown in four days during 12,9 survey hours for the five census blocks (Fig. 1). Animal and water point observations totalled 828 and 60 respectively. A total of 4 973 large herbivores (17 species) and 68 large birds were counted (Appendix B-D). Large carnivores (four species, total 46) and vulture nests (three species, eight nests) were also recorded. An average ground velocity of 175,1 km/hr (σ = 16,9) was registered during the survey.

The recorded positional data facilitated easy and rapid plotting of sightings (Appendix E). A detailed analysis of sampled strip positions and recorded data points indicate that flight paths followed almost straight lines between start and end positions of strips (Fig. 2). No obvious lag effect between the start and end of successive strips was evident as these points were almost all in a straight line on both sides of the area surveyed. No delays during data entry occurred even when animal groups were counted in rapid succession.

The accuracy of the GPS-recorded localities was not tested during the Vlakteplaas East survey. However, it was estimated that positional data of windmills and dams were within 100 m from the true positions of these structures when the aircraft passed overhead. The test flight to determine the accuracy of the GPS during typical aerial survey condi-

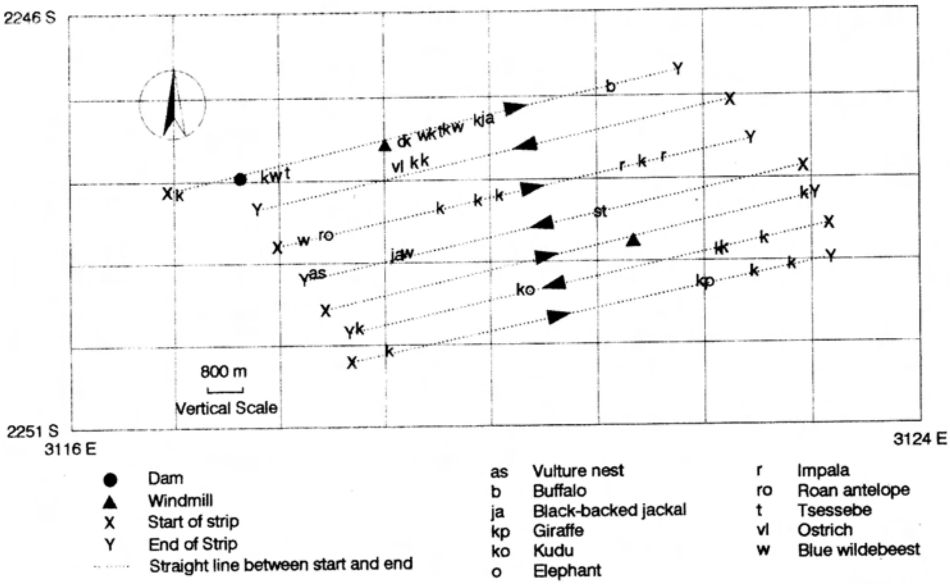

Fig. 2. Example of seven survey strips recorded during an aerial survey of the Boyela Census Block (Census Block ID 48. Vlakteplaas Census Compartment) in the northern KNP (20-24 September 1993). A GPS was used to determine the position of all survey strips and all sightings of animals and surface water.

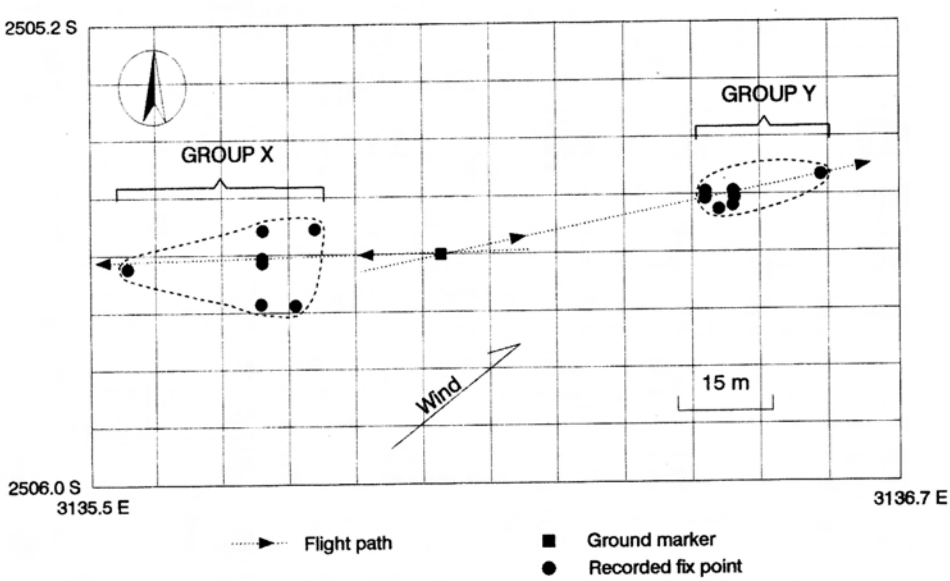

Fig.3. Fix points (waypoints) recorded of a ground marker 5 km south of Skukuza in the KNP using a GPS and connected computer. Fix points in Group X ($n = 7$) and Group Y ($n = 7$) were recorded flying in W and ENE directions respectively.

tions indicated that a minor lag occurred between actually passing overhead the ground marker and the measured fix points (n = 14). Two clusters of fix points (seven fix points in each cluster) were identified on both sides of the marker (Fig. 3). The calculated average distance between the two groups of fix points (Groups X and Y) were 120,0 m while the average distances between the marker and the two fix point groups were 21,1 m and 74,6 m respectively (σ = 9,1 and 3,3 respectively). These distances differed significantly (Mann-Whitney U-test, P = 0,019), most likely as a result of wind which caused a slightly higher ground velocity and therefore a greater lag effect when flying downwind (Fig. 3). The average distance between the fix points and the marker was 60,0 m (σ = 18,8).

Discussion

Real-time entry of observations into a computer results in improved efficiency in data handling and georeferencing, effectively reducing data capturing procedures by eliminating the digitising phase. Data file output (Appendix A) follows the same basic structure currently obtained using a digitiser with the exception of latitude/longitude data replacing cartesian coordinates and the recording of additional data (time and ground velocity). The distribution of surface water was previously digitised to a separate data file but is now combined with animal data in a single file. All data records are therefore immediately available on computer and can be analysed after each survey without delay. Any doubtful data entries can be easily verified and corrected immediately after each survey flight using a text processor. Additional data available from the GPS (for example time and ground velocity) are easily included in the data file which could facilitate further studies on the effect of ground velocity on the number of animals seen.

Using the GPS, all sightings between the flight path and the extreme of the survey strip (400 m from the flight path) are recorded on the centre line of the flight path, resulting in a positional error if animal sightings or water records are not directly on the flight path. However, similar positional errors are no exception during the present system of data recording, particularly when the data recorder has to plot a large number of records when concentrations of animals are encountered. The data recorder then has limited time to locate landmarks visually while plotting the positions of animals.

A GPS for obtaining positional data results in improved accuracy of position records. Real-time accuracy of GPS for civilian users is about 100 m as a result of Selective Availability (SA) which is controlled by the U.S. Department of Defence (DoD). However, experience has shown that horizontal stationary accuracy often falls within a 15-30 m range (Gibbons 1992). Ardö & Pilesjö (1992) calculated a mean error of 17,9 m between a ground reference point and measured fix points while never exceeding 44,0 m using a hand-held GPS. Although a lag effect in recording the position of a specific point was noted during this study, the horizontal accuracy is considered to be well within the required criteria for the EAS.

The use of an infra-red scanner and bar codes to replace keyboard data entries is currently being investigated. This procedure should allow for speedier data capture while eliminating the need for the data recorder to be familiar with species codes. An updated version of the computer program will continually display the position of the aircraft in relation to the expected flight path.

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References

ANON. 1991. Wonder nav for the '90s? *Plane & Pilot* Jan.: 22-26.

ARDO, J. and P. PILESJO. 1992. On the accuracy of the global positioning system - a test using a hand-held receiver. *International Journal of Remote Sensing* 13: 3229-3233.

BOER, A.H., G. REDMOND and T.J. PETTIGREW. 1989. LORAN-C: A navigational aid for aerial surveys. *Journal of Wildlife Management*. 53: 228-230.

BOTHMA, J. DU P. 1989. Game counts. Pp. 290-318. *In*: BOTHMA, J. DU P. (ed.). *Game ranch management*. Pretoria: van Schaik.

COLLINSON, R.F.H. 1985. Selecting wildlife census techniques. Monograph 6. Institute of Natural Resources, University of Natal, Pietermaritzburg.

GIBBONS, G. 1992. The Global Positioning System as a complementary tool for remote sensing and other applications. *Photogrammetric Engineering & Remote Sensing* 58: 1255-1257.

GORMLEY, M. 1990. The GPS solution - is it time to look to the skies?. *Business & Commercial Aviation*. Dec.: 70-74.

GREER, J.D. 1993. The view from above. *Journal of Forestry* 91: 10-14.

JOUBERT, S.C.J. 1983. A monitoring programme for an extensive national park. Pp. 201-212. *In*: OWEN-SMITH, N. (ed.). *Management of large mammals in African conservation areas*. Pretoria: Haum.

LANCE, K. 1993. Bringing technology down to earth. *Journal of Forestry* 91: 17-19.

NORTON-GRIFFITHS, M. 1978. *Counting Animals*. Serengeti Ecological Monitoring Programme Handbook No. 1. Nairobi: African Wildlife Leadership Foundation.

PETERSEN, C. 1990. Into the woods with GPS. *GPS World* Nov./Dec.: 31-36.

SAS INSTITUTE INC. 1991. *Statistical analysis system*. Version 6.04. Cary, North Carolina: SAS Institute Inc.

VILJOEN, P.C. 1989. Ecological aerial surveys in the Kruger National Park: Objectives and Methods. Unpublished report, National Parks Board, Skukuza.

WHITEHEAD, K. 1992. GPS technology review. Report No. FOR-I 194, Division of Forest Science and Technology. CSIR, Pretoria.

Appendix A

Example of ASCII data file generated by using a GPS and computer. The start and end of one strip with animals and water recorded is depicted (Census Block ID 49: Nkulumbeni, Vlakteplaas East Census Compartment)

```
*93:09:22:49
@01:Start at:052351:3113.680000:E:2254.710000:S
052417:3113.950000:E:2255.410000:S:ob:  2:98.200000
052429:3114.080000:E:2255.710000:S:e :  1:95.700000
052435:3114.140000:E:2255.860000:S:ob:  1:95.900000
052441:3114.200000:E:2256.010000:S:ob:  1:95.300000
052447:3114.260000:E:2256.160000:S:kp:  1:93.800000
052455:3114.350000:E:2256.350000:S:ba:  1:92.700000
052502:3114.410000:E:2256.500000:S:kp:  1:92.200000
052510:3114.500000:E:2256.680000:S:r : 15:91.700000
052514:3114.550000:E:2256.770000:S:wb:  2:91.300000
052644:3115.410000:E:2258.940000:S:r : 40:93.900000
052648:3115.450000:E:2259.040000:S:k :  5:93.900000
052652:3115.480000:E:2259.140000:S:xw:  1:93.900000
@01:End at:052710:3115.650000:E:2259.580000:S
@02:Start At:052744:3116.180000:E:2259.820000:S
```

Explanation:

`*93:09:22:49`
Date (93-09-22) and census block ID number (49).

`@01:Start at:052351:3113.680000:E:2254.710000:S`
Start of first strip (01): time (05:23:51 UTC), longitude(E) and latitude (S).

`052417:3113.950000:E:2255.410000:S:ob: 2:98.200000`
Animal observation: time (05:24:17 UTC), longitude (E), latitude (S), species code (ob = elephant bull), number (2) and ground velocity (98.2 knots).

`052652:3115.480000:E:2259.140000:S:xw: 1:93.900000`
Surface water: time (05:26:52 UTC), longtitude (E), latitude (S), water code (xw = windmill), number (1) and ground velocity (93.9 knots).

`@01:End at:052710:3115.650000:E:2259.580000:S`
End of first strip (01): time (05:27:10 UTC), longitude (E) and latitude (S).

Time is recorded in Universal Time (UTC), local time (SA time) = UTC + 2:00.

Appendix B

Large herbivores and carnivores recorded during an aerial survey of the Vlakteplaas Census Compartment in the northern KNP (20-24 September 1993)

Species	Number of obs.	Total
Large Herbivores:		
Blue wildebeest *Connochaetes gnou*	59	192
Buffalo *Syncerus caffer*	36	793
Burchell's zebra *Equus burchellii*	287	2 047
Eland *Taurotragus oryx*	20	45
Elephant *Loxodonta africana*	85	467
Giraffe *Giraffa camelopardalis*	29	58
Impala *Aepyceros melampus*	100	1 017
Kudu *Tragelaphus strepsiceros*	15	57
Lichtenstein's hartebeest *Sigmoceros lichtensteinii*	11	23
Nyala *Tragelaphus angasii*	5	12
Reedbuck *Redunca arundinum*	3	4
Roan antelope *Hippotragus equinus*	9	28
Sable antelope *Hippotragus niger*	19	60
Steenbok *Raphicerus campestris*	21	21
Sassaby *Damaliscus lunatus*	25	70
Warthog *Phacochoerus aethiopicus*	3	9
Waterbuck *Kobus ellipsiprymnus*	19	70
Large Carnivores:		
Black-backed jackal *Canis mesomelas*	6	7
Honey badger *Mellivora capensis*	1	1
Lion *Panthera leo*	10	37
Spotted hyaena *Crocuta crocuta*	1	1
Three baboon troops *Papio ursinus* were also recorded		

Appendix C

Large bird species recorded during an aerial survey of the Vlakteplaas Census Compartment in the northern KNP (20-24 September 1993)

Species	Number of obs.	Total
Birds:		
Bateleur *Terathopius ecaudatus*	11	11
Ostrich *Struthio camelus*	27	52
Saddlebilled Stork *Ephippiorhynchus senegalensis*	1	3
Secretary Bird *Sagittarius serpentarius*	2	2
Vulture nests:		
Lappetfaced Vulture *Torgos tracheliotus*	4	4
Whitebacked Vulture *Gyps africanus*	2	2
Whiteheaded Vulture *Trigonoceps occipitalis*	2	2

Appendix D

Surface water recorded during an aerial survey of the Vlakteplaas Census Compartment in the northern KNP (20-24 September 1993)

Water type	Total
Dam	5
Pan	4
Pool	23
Windmill	28

Appendix E

Distribution of windmills (troughs with water), zebra and roan antelope recorded during an aerial survey of the Boyela Census Block (Valkteplaas East Census Compartment)