Pirineos, 157: 7 a 13, JACA; 2002

FEASIBILITY OF GPS USE TO LOCATE WILD UNGULATES IN HIGH MOUNTAIN ENVIRONMENT

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ABSTRACT.– Fix success and accuracy of GPS (Global Positioning System) telemetry both depend on the number of visible satellites and their geometry. Due to the topography of the mountain environment the efficiency of GPS is compromised, field tests were conducted to analyze how it can affect fix success and rate of 3D locations (≥ 4 visible satellites) as regards slope orientation, using pooled data from GPS collars in solved- and differential-mode. Ten test sites were defined in the periphery of the Vanoise National Park. Fixes were simultaneously recorded at the bottom and top of cliffs facing each of the 4 main orientations or at the bottom of valleys oriented E-W and N-S and at a reference site (open field). Fix success and rate of 3D locations were significantly negatively correlated with an increasing obstruction level. Cliff orientation affected both fix success (significantly higher for cliffs facing the North) and rate of 3D locations (significantly higher for cliffs facing the South).

RÉSUMÉ.– Dans la télémétrie par GPS (Global Positioning System), la fixation d'un point et la précision se montrent conditionnées par le nombre de satellites visibles et la géométrie. Les montagnes provoquant des obstructions topographiques qui réduisent la fiabilité du GPS, nous avons effectué des essais de terrain pour analyser comment l'exposition du versant peut affecter la fixation d'un point ou le taux de localisation 3D (4 satellites visibles ou plus). Pour cela nous avons utilisé un ensemble de données GPS. Nous avons marqué 10 points de référence en périphérie du Parc National de la Vanoise. Puis nous avons enregistré simultanément des points fixes en fond de vallée et en haut des falaises exposées aux quatre directions principales ou au fond des vallées orientées E-W et N-S ainsi que dans un point de référence (champ ouvert). La fixation d'un point ainsi que le taux de localisation en 3D montraient significativement une corrélation négative avec un niveau croissant d'obstruction. L'exposition de la falaise affectait le succès de la localisation (tout spécialement les falaises exposées au nord) et également le taux de localisation en 3D (significativement plus haut pour les falaises exposées au sud).

RESUMEN.– El éxito en la ubicación y la exactitud de la telemetría por medio de GPS (Global Positioning System) depende del número de satélites visibles y de su geometría. Las montañas suponen obstrucciones topográficas, reduciendo así la fiabilidad del GPS. Se realizó un test de campo para analizar su efecto sobre el éxito en la ubicación y la proporción de localizaciones en 3D (> 4 satélites visibles), teniendo en cuenta la orientación de la pendiente y usando como fuente datos el GPS de collares emisores. Se seleccionaron diez puntos de muestreo en la periferia del Parque Nacional de La Vanoise. Las localizaciones se tomaron simultáneamente en el fondo y en lo alto de riscos orientados hacia cada uno de los 4 puntos cardinales, en el fondo de valles orientados E-W y N-S y en un lugar de referencia (campo abierto). El éxito en la ubicación y la proporción de localizaciones en 3D fue significativamente negativo para un nivel de obstrucción creciente. La orientación del roquedo afecta tanto al éxito de la ubicación (significativamente mayor para roquedos de orientación norte) como a la proporción de localizaciones en 3D (significativamente mayor para roquedos de orientación sur).

Key-words: Global Positioning System, topographic obstruction, slope orientation, mountain ungulates, ibex.

1. Introduction

Global Positioning System (GPS) has been used to track wild animals since the nineties (RODGERS & ANSON, 1994). This location technique is based on collars housing GPS receivers which use information from satellites orbiting the Earth to calculate their location at regular time intervals. This system generates precise data on the movements of animals with minimal human intervention. Fix success and accuracy depend on visible satellites number and geometry (WELLS, 1986). At least 3 satellites are needed to record a 2-dimensional (2D) location and 4 satellites allow recording a 3-dimensional (3D) location. In addition, DOP (Dilution of Precision) values can be used to specify fix accuracy according to satellites geometry. Researchers have tested the performance of this technique with respect to location accuracy (REMPEL *et al.*, 1995; EDENIUS, 1997; MOEN *et al.*, 1997; REMPEL & RODGERS, 1997; JANEAU *et al.*, 1998; BOWMAN *et al.*, 2000; DUSSAULT *et al.*, 2001; ADRADOS *et al.*, 2002). GPS users must also be concerned with the effect of obstacles such as tree canopy and topography, which may limit the performance of GPS receivers. Most tests of GPS performance with regards to obstruction have been conducted in boreal forest (REMPEL *et al.*, 1995; MOEN *et al.*, 1996; EDENIUS, 1997; REMPEL & RODGERS, 1997; OBBARD *et al.*, 1998; DUSSAULT *et al.*, 1999). GPS performance decreases as trees get taller (MOEN *et al.*, 1996; EDENIUS, 1997; REMPEL & RODGERS, 1997; DUSSAULT *et al.*, 1999; JANEAU *et al.*, 2001) and when canopy closure (REMPEL *et al.*, 1995), tree density (REMPEL & GOADSBY, 1992; REMPEL *et al.*, 1995) and tree basal area (REMPEL *et al.*, 1995; MOEN *et al.*, 1996; EDENIUS, 1997; DUSSAULT *et al.*, 1999; JANEAU *et al.*, 2001) increase.

Relevant experimental data was not found in the literature concerning topographic obstruction. For this reason, we decided to test the effects of topographic obstruction and slope orientation (satellites geometry) on fix success in high mountain environment, before deployment of GPS collars on Ibex.

Our aim was to evaluate the effects of topographic obstruction, which is the main limit of GPS use in high mountain environment (Trimble Navigation Ltd. 1996), and slope orientation on GPS performance (fix success and rate of 3D locations).

2. Material and Methods

Study area: Tests were conducted in the Grande Sassière Nature Reserve, at the periphery of the Vanoise National Park (France, approx. 7°00′ E and 45°48′ N), in a 2 km glacial valley (2300 m-3750 m), mainly oriented from E to W and covered by alpine meadows. The slopes comprise rocky cliffs and masses of fallen rocks. A second site was located 6 km far to the South in a 3 km N-S valley (1850 m-2850 m), covered by alpine meadows and rocky cliffs. Because of the altitude, canopy does not constitute a limiting factor on satellite visibility.

GPS receivers and Software: We used 3 differential 8-channel GPS_1000 collars and 1 non-differential 8-channel GPS_2000 collar from Lotek Engineering Inc. (Canada), and 3 non-differential 8-channel GPS Simplex collars from TVP Positioning AB (Sweden). Data collected were processed using Gpshost software (Lotek collars) and Simpset 2.0 (TVP Positioning collars). Differential corrections were post-processed using N4Win software (Lotek differential collars). Due to different DOP calculation modes according to firms, we did not use this parameter.

Tests: GPS recordings were conducted on 23rd and 24th August 1999 on 10 various places of the study area: bottom and top of cliffs facing one of the 4 main directions (N, S, W, E) and bottom of valleys oriented E-W or N-S. 30 fixes were attempted simultaneously (5 min interval) at the top and bottom of each cliff or in valleys bottom using 2 GPS collars (one of each firm). Concurrently, a reference collar was settled using the same schedule in an open zone of the study area to assess satellites visibility during the study period. Topographic obstruction (i. e., under this value, in degrees, natural barriers prevent satellite signal reception) was evaluated for each position (top and bottom of cliffs) and main orientation (N, S, W, E).

Data treatment: Results coming from the various GPS collars were pooled to assess global effects of mountain environment on GPS collars performance, estimated as the rate of successful locations (i.e. number of recorded locations/number of expected ones) and the rate of 3D locations (i. e. number of 3D locations/number of successful ones). χ^2 tests wree used to analyze GPS collars performance regarding to collars position (bottom of valley vs. cliffs, top of cliffs vs. bottom, one direction vs. an other). In addition, both rates of successful and 3D locations were correlated to topographic obstruction (using the maximal value per position) and complemented by a t-test. Statistical analyses were performed using STATISTICA software (α value was 0.05).

3. Results

747 (87%) successful locations among 858 expected were obtained, 605 (81%) of them being 3D locations. The reference collar recorded 100% of the expected locations (n=163), all 3D locations, and showed that at least 7 satellites were visible during the whole study period.

Effects of topographic obstruction on GPS performance:

Higher rates of successful locations (χ^2=23.00, df=1, p<10^{-3}) and 3D locations (χ^2=15.00, df=1, p<10^{-3}) were recorded at the bottom of valleys rather than on the cliffs (Table 1). Accordingly, GPS performance was higher at the top of cliffs than at the bottom (χ^2=27.34, df=1, p<10^{-3} and χ^2=43.00, df=1, p<10^{-3} for the rates of successful locations and 3D locations, respectively; Table 1).

Table 1. GPS collars performance according to collars position and topographic obstruction (°). Thick values outline the highest topographic obstruction for each position.

Collars position	*Cliff facing the*	*Expected fixes*	*Location rate (%)*	*3D location rate (%)*	*Topographic obstruction (°)*			
					North	*East*	*South*	*West*
Bottom	North	66	85	55	23.2	8.7	*82.9*	2.4
	East	74	68	46	14.6	8.9	19.4	*88.6*
	South	87	64	80	*86.4*	17.7	15.1	4.7
	West	66	68	38	12.9	*85.2*	9.5	1.0
Total bottom		*293*	*71*	*56*				
Top	North	64	91	84	*21.8*	3.3	13.2	2.2
	East	74	84	90	*14.0*	7.7	6.8	11.3
	South	71	99	83	*40.6*	11.3	12.1	3.5
	West	66	92	79	10.1	*33.7*	10.9	1.4
Total top		*275*	*91*	*84*				
Total cliffs		*568*	*81*	*71*				
Bottom of an East-West valley		65	97	89	*32.1*	13.5	20.3	4.0
Bottom of a North-South valley		62	100	89	12.1	*21.8*	14.7	13.4
Total valley bottom		*127*	*98*	*89*				
Reference point		163	100	100	*32.1*	13.5	20.3	4.0

Rates of both successful locations and 3D locations were negatively correlated with topographic obstruction (R_=0.63, t=-3.73, p=0.006 and R_=0.67, t=-4.06, p=0.004, respectively; Figure 1). Fix success and rate of 3D locations were >80% when topographic obstruction was ≤40°. Fix success remained >60% even with a high topographic obstruction (>80°), whereas rate of 3D locations decreased under 50% when topographic obstruction was >80°.

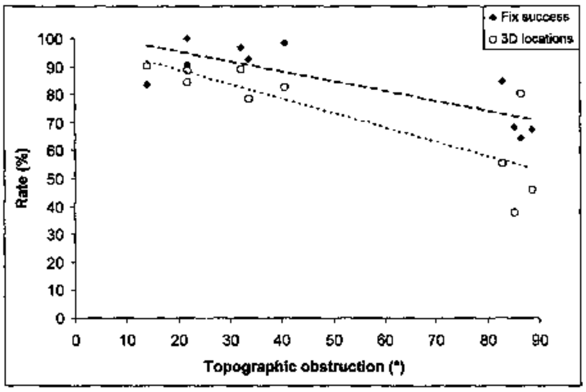

Figure 1. Rates of fix success and 3D locations according to topographic obstruction.

Effects of slope orientation on GPS performance:

When collars were situated on top of cliffs, no difference was detected in rate of successful locations amongst orientations (Table 2) except when comparing East to South. Conversely, differences appeared when collars were located at the bottom of cliffs. A significant upper rate of successful locations appeared when the South part of the sky was hidden. In this case, we found no difference between top vs. bottom of the cliffs (χ^2=1.00, df=1, p=0.316).

Table 2. Differences between rates of successful locations and 3D locations according to slope orientation.

Directions	*Top position*				*Bottom position*			
	Location rate		*3D location rate*		*Location rate*		*3D location rate*	
	χ^2	p	χ^2	p	χ^2	p	χ^2	p
N – E	0.88	0.349	0.48	0.490	5.67	0.017	0.93	0.336
N – S	2.88	0.090	0.00	0.994	8.02	0.005	8.02	0.005
N – W	0.00	0.958	0.33	0.564	5.10	0.024	3.09	0.079
E – S	8.00	0.005	0.99	0.321	0.18	0.670	13.56	$<10^{-3}$
E – W	1.70	0.193	2.36	0.125	0.01	0.938	0.66	0.418
S – W	1.81	0.179	0.15	0.702	0.24	0.622	19.08	$<10^{-3}$

Rate of 3D locations did not differ amongst orientations when collars were situated on top of cliffs but significant differences appeared when collars were at the bottom of cliffs (Tables 1 and 2). Rate of 3D locations was significantly higher when the North part of the sky was hidden. As previously, we detected no difference according to collar position (top vs. bottom of cliffs: χ^2=0.13, df=1, p=0.718).

4. Discussion and Conclusion

The results show that topography could interfere with data collection. The heterogeneous distribution of satellites constellation (i.e., satellites geometry is generally better in the South part of the sky under our latitude) can explain cliff orientation effects (TRIMBLE, 1996).

According to JANEAU (2000) and HALLER *et al.* (2001), our results on topographic obstruction and slope orientation exhibit the feasibility of using GPS technology as a good alternative to other location techniques for animals inhabiting high mountain areas. Due to significant technical enhancements of GPS collars since 1999, we can speculate that GPS performance has increased.

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