Role of GPS in Monitoring Livestock Migration

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Abstract: Satellite-based technique of global positioning systems (GPS) is useful for tracking long-distance livestock movement across the grazing routes and to study the specific needs of livestock herders. There are two kinds of GPS tracking systems: live and real-time tracking, and passive tracking. Real-time GPS tracking is used to keep an eye on livestock and it has the ability to monitor spatial movements and spatial activities. Such GPS devices provide information for multiple benefits i.e., movements of livestock throughout the landscape, grazing and watering patterns, and areas where the livestock deplete nutrients in the soil. Passive GPS tracking systems are able to record information on livestock mobility and identify key areas actively utilized by livestock. In the present study, Clark Animal Tracking System (Clark ATS Plus) was deployed to study the migration pattern of livestock (cattle, sheep and goat) of Western Rajasthan, which records data at hourly intervals and position (latitude and longitude), date, time, fix quality, and animal velocity on secure digital cards in the collar. Present paper discusses the use of satellite tracking in studying animal migration by elucidating migration routes, stopover sites, average speeds, and total migration time and distance for formulating appropriate range management strategies.

Introduction

In western Rajasthan pastoral system of livestock rearing has evolved over the last five centuries. The system has developed traditional migration routes and a partition of responsibilities, with some castes specializing in animal herding and others with crop production (Malhotra and Mann, 1982). Because forage resources develop and change with the seasonal monsoon and its effects across the regional landscape, the livestock production system includes migration (Kavoori, 2005). Animal migration mitigates impact from drought, lack of forage, and ephemeral water resources for pastoralists allowing them to lead productive lives.

The recent advances in animal tracking technology have resulted in large volumes of data becoming available for analysis. Telemetry systems based on the Global Positioning System (GPS) is a relatively recent development (Rodgers and Anson, 1994; Rodgers, et al., 1996; Agouridis, et al., 2004) for monitoring movement (Brosh, et al. 2006), their activity (Ungar et al., 2005), and resource use by medium- to large-sized animals (Moura˜o and Medri, 2002; Bailey, et al. 2006). The GPS technology has enabled researchers to record the sequential movement patterns of animals and compile datasets with many observations compared with older tracking techniques over a similar period of time (Jonsen, et al., 2005). GPS-enabled livestock tracking system (LTS) can be used to monitor the activity of livestock (i.e., walked distance, speed, grazing and resting time (Trotter, et al., 2010)), the habitat preferences (i.e. grazing sites and intensity, resting sites (Putfarken, et al., 2008)) and thus to support the herdsman. In several cases the LTS was additionally supplemented with sensors for heat and/or health monitoring (Nagl, et al., 2003).

GPS receivers in a lightweight collar or harness can be deployed for extended periods with little effect on behavior. Units

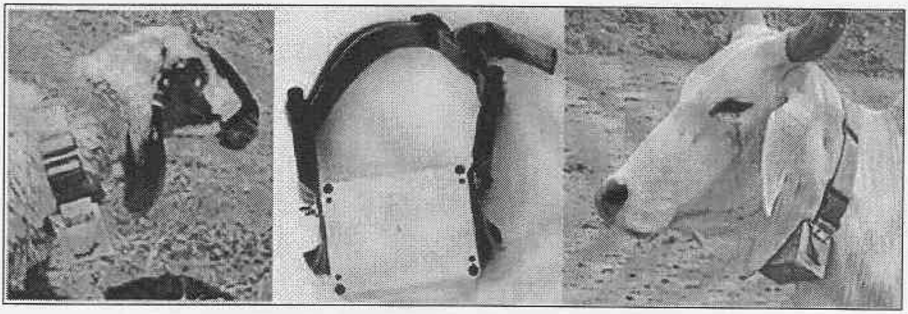

Fig. 1: Clark ATS Plus GPS Collar

derive coordinates from an internal receiver tracking an array of 24 earth-orbiting satellites. Coordinates are stored in onboard memory for later retrieval to the computer.

Historical Perspective

Satellite-based global positioning systems (GPS) have provided novel and unique data. These have been used to track animal movement. Livestock scientists have used GPS data to understand behavioral differences in free-grazing experiments. With a shift in focus, from the environment to the animal, brings the challenge of ensuring independence of the experimental unit. Social facilitation challenges independence of the individual in a group. The use of spatial modeling methods to process GPS data provides an opportunity to determine the degree of independence of data collected from an individual animal within behavioral-based studies. By using location and movement information derived from GPS data, researchers have been able to determine the environmental impact of grazing animals as well as assessing animal responses to management activities or environmental perturbations. Combining satellite-derived remote-sensing data with GPS-derived landscape preference indices provides a further opportunity to identify landscape avoidance and selection behaviors.

The first study to use GPS in locating animals began in March 1994 using collars designed and manufactured by Lotek Engineering Inc. (Newmarket Ontario, CA; Rodgers and Lawson, 1997). GPS has been used successfully to track domestic sheep (Roberts et al., 1995; Rutter et al., 1997; Hulbert et al. 1998) and cattle (Udal et al., 1998; Turner et al., 2000; Schlecht et al. 2004; Ungar et al. 2005; Ganskopp and Bohnert, 2006) as well as numerous wildlife species (Austin and Pietz, 1997; Mech and Barber, 2002) with spatial accuracies never before possible (Tomkiewicz, 1997; Hulbert and French, 2001).

GPS Collar Sampling Protocol

The Clark ATS+ collar rigging consists of a collar belting assembly and an electronics enclosure. The enclosure is a two-piece, polycarbonate, water-tight box which houses and protects the electronics package of the collar. The belting assembly serves to attach the electronics enclosure around an animal's neck and it also houses and protects the GPS and satellite modem antennas and associated cables. GPS collars are supported by an 8-channel receiver (Lotek HGPS2200 LR; Lotek Engineering Inc., Newmarket, Ontario, Canada) is capable of simultaneously tracking #8 satellites. Records are written to onboard, non-volatile random access memory retaining a maximum of 5028 differentially correctable coordinates. Each record includes collar number, date, time, longitude and latitude, elevation, a dilution of precision value (an index of satellite geometry reflecting position accuracy), a 2- or 3-dimension fix status (2-dimension records are derived from a minimum of three satellites with no elevation estimate, whereas 3-dimension records use 4 satellites and generate an elevation measure), ambient air temperature, and satellite information used for differential correction (Fig. 1). Figure 2 displays components of GPS positioning and data storage in the collars which is suitable for deployment in livestock herds.

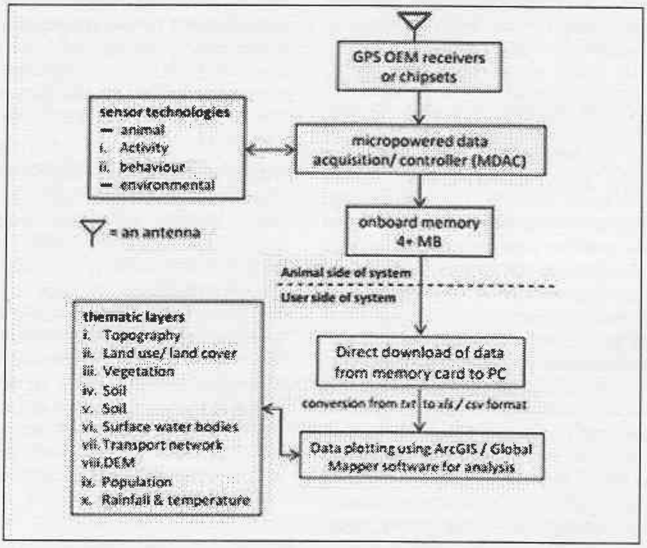

Fig. 2. Block diagram showing the components of a GPS positioning and data collection system suitable for deployment on animals. (Source: Tomkiewiez, et. al., 2010)

There are two kinds of GPS technology available for livestock monitoring: real-time and passive. Real-time GPS monitoring is used to keep an eye on livestock having the ability to monitor spatial movements and spatial activities, information that can provide multiple benefits. GPS live monitoring data transmitted from livestock helps herders understand a great deal about how livestock interact with the precious lands and also gives them the ability to discover a farm animal's precise location. Passive GPS tracking systems gathers information about livestock. The tracking collars are worn on the animal as a collar, and if or when the herder wants to collect and review that recorded tracking data, the collar is manually removed and the stored data is downloaded. It allows them to view the movements of the livestock, in retrospect. However, it is believed that there will be a dynamic shift and movement toward real-time solutions as the technology becomes more tailored and cost-effective. It is useful to track the movement and grazing behavior of cattle flock and sheep herds. It helps to understand the way herders manage their cattle in large herds. Distances and speeds travelled by the cows and sheep, including how long the cows spend lying down, grazing, and, importantly, the number of hours during the day that they are unable to either feed or lie down.

Rajasthan Study

Four districts from western Rajasthan (Pali, Jodhpur, Barmer and Jalore) with significant numbers of migratory cattle or small ruminant flocks were selected for study. Cows and sheep were fitted with Clark Animal Tracking System (ATS) collars that recorded date, time, and position at 1 hour intervals during migration. People from Jodhpur, Barmer, Pali and Jalore districts generally migrate towards Uttar Pradesh, Madhya Pradesh and Haryana. The exact routes of cattle migration, time taken to reach watering points as well as the total distance travelled has been mapped and calculated through GPS Collars.

Analysis of a 20 km land use/land cover buffer on the migration route reveals that 0.06 per cent of the urban land, 29.06 per cent of cropland and 48.57 per cent of fallow lands was utilized by migrating animals for grazing and resting purposes. It has been observed through the GPS data analysis that animal drink water once a day and if available, it may be twice a day. Sometimes, they have to cover 18-22 kms, from the migration route, to locate a water body. The animals on an average travelled 7.09 km before migration, 8.8 Km during migration and 8.71 Km / day across the entire observation period. Further, cattle have travelled from Motisara village (Siwana tehsil, Barmer district) to Jajjar (Haryana State) covering around 1550 kms from January, 2013 to June, 2013.

Limitations of GPS Collars

It was not until the end of the 1990's that animal born satellite receivers catapulted range cattle ecology into the 21st century world of microchip technology with all of its opportunities and challenges. With the global navigation satellite system (GNSS), insight about how cattle use a landscape is being revealed from previously unknown temporal and spatial behaviors. The most common system to date for studying ungulate movement is the global positioning system (GPS). With its use has come a clarity and completeness in documenting spatial and temporal data in new and exciting ways that offer almost unlimited possibilities to better understand and manage economic and societal returns from animal dominated landscapes. However, its use on free-ranging cattle is not without challenges, some of which are yet to be optimally solved. To maximize the usefulness of GNSS data, consideration must be given to: (1) developing a standardized protocol for reporting and analyzing research that facilitates interpretation of results across different ecosystems; (2) develop optimum ranges over which to collect satellite fixes depending upon the particular behaviors of interest; and (3) concurrently develop electronic hardware and equipment platforms that are easily deployed on animals and that are light, robust, and can be worn by cattle for extended periods of time without human intervention (e.g., changing batteries). Once data are collected, appropriate geographic information system (GIS) based models should be used to produce a series of products that can be used to implement flexible management strategies, some of which may support methodologies that are yet to be commercialized and adopted into future plant-animal interface management routines.

Tracking animals with GPS provides useful information, but the cost of the technology often limits experimental replication. Limitations on the number of devices available to monitor the behavior of animals, in combination with technical constraints, can weaken the statistical power of experiments and create significant experimental design challenges.

As spatial livestock monitoring tools become more widely used, there will be a greater need to ensure the data and associated processing methods are able to answer a broader range of questions. Experimental design and analytical techniques need to be given more attention if GPS technology is to provide answers to questions associated with free-grazing animals.

Conclusion

GPS-based, animal tracking technologies has been invaluable in studying animal migration by elucidating migration routes, stopover sites, average speeds, and total migration time and distance. It has made it possible to make season-long evaluations of livestock distribution and activity patterns at very fine-scale temporal (300 sec) and spatial (<1 m) resolution. Particularly in conjunction with biotelemetry, it can provide valuable information on the study of migration physiology. It is also possible to conduct shorter-term intensive evaluations (e.g., 1-sec sampling interval) of behavioral and energetic differences. Since movement of animals is an important component of many ecological processes, combined with remote sensing and GIS data and analysis tools, GPS tracking technologies provide a powerful means of monitoring or assessing animal behavior within both research and management contexts. It further provides data on barriers to migration as well as allows researchers to devise strategies to minimize anthropogenic impacts on migratory livestock.

References

Agouridis C.T., Stombaugh T.S., Workman S.R., Koostra B.K., Edwards D.R. and Vanzant E.S. 2004. Suitability of a GPS collar for grazing studies. *Transactions of the American Society of Agricultural Engineers*, 47, 1321-1329.

Austin, J. E., and Pietz, P. J. 1997. Forum on wildlife telemetry. *In*: 'The Wildlife Society and Biological Resources Division'. (Chairpersons J. E. Austin and P.J. Pietz.) pp. 1–82. (US Geological Survey: Snowmass Village, CO.)

Bailey, D. W., H. C. Vanwagoner, and R. Weinmeister. 2006. Individual animal selection has the potential to improve uniformity of grazing on foothill rangeland. *Rangeland Ecology & Management*, 59:351–358.

Brosh, A., Z. Henkin, E.D. Ungar, A. Dolev, A. Orlov, Y.Yehuda, and Y. Aharoni. 2006. Energy cost of cows' grazing activity: use of the heart rate method and the global positioning system for direct field estimation. *Journal of Animal Science*, 84:1951–1967.

Clark, P.E., Johnson D.E., Kniep M.A., Jermann P., Huttash B., Wood A., Johnson M., McGillivan C. and Titus K. 2006. An advanced, low-cost, GPS-based animal tracking system. *Rangeland Ecology and Management*, 59, 334-340.

Ganskopp, D., and Bohnert, D. 2006. Do pasture-scale nutritional patterns affect cattle distribution on rangelands? *Rangeland Ecology and Management* 59, 189–196. doi: 10.2111/04-152R1.1

Hein, G. W.,´ Avila-Rod´riguez, J. A., Wallner, S., Eissfeller, B., Pany, T., and Hartl, P. 2007. Envisioning a future GNSS system of systems, part 1. *Inside GNSS*, 2, 58–67

Hulbert, I. A. R., and French, J. 2001. The accuracy of GPS for wildlife telemetry and habitat mapping. *Journal of Applied Ecology* 38, 869–878. doi: 10.1046/j.1365-2664.2001.00624.x

Hulbert, I. A. R., Wyllie, J. T. B., Waterhouse, A., French, J., and McNulty, D. 1998. A note on the circadian rhythm and feeding behavior of sheep fitted with a lightweight GPS collar. *Applied Animal Behaviour Science*, 60, 359–364. doi: 10.1016/S0168-1591(98)00155-5

Jonsen, I.D., Flemming, J.M., Myers, R.A. 2005. Robust state-space modeling of animal movement data. *Ecology* 86(11):2874-2880.

Kavoori, P. S. 2005. *Pastoralism in Expansion, The transhuming herders of western Rajasthan*. Oxford University Press, 226p.

Malhotra, S.P. and Mann, H.S. 1982. Desertification and the organization of society. *In* Spooner B., Mann H.S. eds., *Desertification and Development: Dryland Ecology in Social Perspective*. Academic Press, London pp. 305-310.

Mech, D. L., and Barber, S. M. 2002. A critique of wildlife radio-tracking and its use in national parks: a report to the U.S. National Park Service. Publication 1164. U.S. Geological Survey, Northern Prairie Wildlife Research Center, Jamestown.

Moura˜O, G., and I. M. Medri. 2002. A new way of using inexpensive large-scale assembled GPS to monitor giant anteaters in short time intervals. *Wildlife Society Bulletin*, 30:1029–1032.

Nagl, L., Schmitz R., Warren S., Hildreth T.S., Erickson H. and Andresen D. 2003. Wearable sensor system for wireless state-of-health determination in cattle. *In:* Engineering in Medicine and Biology Society, 2003. The 25th Annual International Conference of the IEEE, IEEE, 3012-3015.

Putfarken D., Dengler J., Lehmann S. and Haerdtle, W. 2008. Site use of grazing cattle and sheep in a large-scale pasture landscape: A GPS/GIS assessment. *Applied Animal Behaviour Science*, 111, 54-67.

Roberts, G., Williams, A., Last, J. D., Penning, P. D., and Rutter, S. M. 1995. A low-power post processed DGPS system for logging the locations of sheep on hill pastures. *Navigation* 42, 327–336.

Rodgers, A. R., and Lawson, E. J. G. 1997. Field trials of the Lotek GPS collar on moose. In: 'The Wildlife Society and Biological Resources Division'. (Chairpersons J. E. Austin and P. J. Pietz.) pp. 58. (U.S. Geological Survey: Snowmass Village).

Rodgers, A. R., R. S. Rempel, and K. F. Abraham. 1996. A GPS-based telemetry system. *Wildlife Society Bulletin*, 24:559–566.

Rodgers, A. R., and P. Anson. 1994. Animal-borne GPS: tracking the habitat. *GPS World*, 5:20–32.

Rutter, S. M., Beresford, N. A., and Roberts, G. 1997. Use of GPS to identify the grazing areas of hill sheep. *Computers and Electronics in Agriculture* 17, 177–188. doi: 10.1016/S0168-1699(96)01303-8

Schlecht, E., Hulsenbusch, C., Mahler, F., and Becker, K. 2004. The use of differentially corrected global positioning system to monitor activities of cattle at pasture. *Applied Animal Behaviour Science*, 85, 185–202. doi: 10.1016/j.applanim.2003.11.003

Tomkiewicz, Stanley M., Mark R. Fuller, John G. Kie and Kirk K. Bates. 2010. Global positioning system and associated technologies in animal behaviour and ecological research. *Phil. Trans.R. Soc. B.* 365, 2163–2176. doi:10.1098/rstb.2010.0090 (accessed on 27 December, 2013)

Tomkiewicz, S. M. Jr. 1997. Advancements in the use of GPS technology in obtaining position information from free-ranging wildlife. In: 'The Wildlife Society and Biological Resources Division'. (Chairpersons J. E. Austin and P. J. Pietz.) p. 70. (U.S. Geological Survey: Snowmass Village.)

Trotter, M.G., Lamb, D.W., Hinch, G.N., Guppy, C.N. 2010. Global Navigation Satellite Systems (GNSS) livestock tracking: system development and data interpretation. *Animal Production Science*, 50: 616-623.

Turner, L. W., Udal, M. C., Larson, B. T., and Shearer, S. A. 2000. Monitoring cattle behavior and pasture use with GPS and GIS. *Canadian Journal of Animal Science* 80, 405–413

Udal, M. C., Turner, L. W., Larson, B. L., and Shearer, S. A. 1998. GPS tracking of cattle on pasture. *In:* 'Presented at the July 1998 American Society of Agricultural Engineers Meeting'. Paper No. 983134. (ASAE: St. Joseph, MI.)

Ungar, E.D., Henkin, Z., Gutman, M., Dolev, A., Genizi, A., Ganskopp, D. 2005. Inference of animal activity from GPS collar data on free-ranging cattle. *Rangeland ecology and management*, 58, 256-266. doi: 10.2111/1551-5028(2005)58[256:IOAAFG]2.0.CO;2

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