IALC Peace Fellowship
Final Report: 15 July – 19 August 2007

Barbara Witmore
Graduate Student, Department of Animal & Range Sciences

New Mexico State University

The Behavioral Timeline of Sheep on Semiarid Rangelands and Its Inference Using GPS and Pedometry

OVERVIEW OF FELLOWSHIP TIME

Participation in the IALC Wayne Owens Peace Fellowship Program gave me the opportunity to work cooperatively with researchers in Israel. It was an intensive five weeks, starting with a seminar the day after I arrived, two days of touring research areas, and a month-long research project on how animals interact with the semiarid landscape under traditional Bedouin management, for which I continued to collect data to the end of my stay. I was honored to work under the supervision of Dr. Eugene Ungar, a research scientist at the Institute of Plant Sciences, Agricultural Research Organization - the Volcani Center, Bet Dagan, Israel. The fellowship enabled continued research in relation to the IALC funded project: "Ecological Processes Enhancing Sustainable Grazing in Semiarid Ecosystems". This project had laid the foundations for a sustained research effort at the Lehavim station in the northern Negev region of Israel. The whole staff, under the direction of Avi Perevolotsky, is very proficient in their fields of expertise and was willing to share their knowledge with me. I had the pleasure of working with several of the staff on field days at the Lehavim research site and in analyzing data upon return to the main office at the Volcani Center. Working with Amir Arnon, performing research also at Lehavim, on the

spatial heterogeneity of sheep and goat grazing using GPS and GIS analysis, allowed me to examine conceptual and analytic approaches used for this study in comparison to methodologies used at New Mexico State University. My main project, that entailed cooperatively working with a Bedouin sheep-herding family, promoted the goals of the Peace Fellowship program of gaining understanding in enhancement of sustainable grazing in semi-arid ecosystems. One professional goal of participating in this fellowship was to create a link between labs from New Mexico State University and Israel with potential for continued collaboration. Both parties will be attending the Meeting of the Society for Range Management and the American Forage and Grassland Council Meeting in late January 2008 which will give opportunity for more detailed discussion on potential cooperative research. I would like to take this opportunity to express my sincerest gratitude to the IALC Wayne Owens Peace Fellowship Program for funding this fruitful fellowship in Israel.

MAIN PROJECT REVIEW

The behavioral timeline of sheep on semiarid rangelands and its inference using GPS and pedometry

INTRODUCTION

A universal feature of extensive, semiarid rangelands is high spatial heterogeneity of their utilization by livestock. This heterogeneity may derive from features of the landscape, such as topography and forage availability, as well as from features of the management system, such as shepherding versus free-ranging and the placement of watering and supplementation points. Because of this heterogeneity, the expression of stocking rate as the ratio of the total number of animals on a farm, station or site, divided by its area, has limited biological meaningfulness, and is a poor predictor of processes such as degradation and desertification. An understanding of the impact of livestock on the landscape requires spatially explicit study of its utilization.

Historically it has been very difficult to study the spatial component of landscape use by animals. However, the relatively recent application of the Global Positioning System (GPS) to the study of grazing systems has

constituted a quantum leap in our ability to track many species of livestock and wildlife. Within range management research it is now commonly employed to monitor and analyze areas of use by livestock solely or in combination with wildlife.

Animal-borne GPS devices provide a continuous and accurate record of animal location over time. However, location alone does not provide a complete picture for the purposes of estimating the spatial distribution of grazing pressure, because animals do not actively graze all the time. They divide their time among different activities, such as resting, traveling without grazing, and active grazing. It would be a great enhancement of GPS data if we could additionally infer the behavioral timeline of the animal. Some GPS devices incorporate motion sensors which can give some indication of activity. For example, the Lotek GPS collars include motion sensors in two axes that store the number of movements registered by the sensors during each GPS fix interval. These values, in conjunction with the distance between consecutive GPS locations, can be used to calibrate statistical models for the inference of animal activity (Ungar et al. 2005).

Before one can apply any kind of sensor technology to the inference of the behavioral timeline of an animal, it is important to establish and align the transitional resolution of the behavior with the resolution of the technology. By transitional resolution, indicating the rapidity with which the animal transitions from one activity to another. If, for example, the animal switches from one activity to another every two minutes, and technology only enables tracking location with a fix interval of 20 minutes, then there is clearly a misalignment between the two resolutions creating inability to infer the detailed behavioral timeline of the animal from such GPS data.

This study examined the behavioral timeline of sheep on a hilly, semiarid landscape in Israel under traditional Bedouin management. There were two main objectives of the study: i) to describe the behavioral timeline of the animal and determine its transitional resolution; and ii) to test our ability to infer the behavioral timeline by using GPS tracking technology as well as an advanced pedometric device. Why is it of particular interest to predict activities of grazing livestock in this environment? Actual consumption of forage is the determining factor for utilization of rangelands. Most methods to monitor utilization are based on comparative measurements of forage plants. Another predictive tool to estimate forage consumption would be in estimating time animals are actually grazing and their speed of movement during grazing and thus estimate forage utilization.

As a result of heterogeneity found on most landscapes, utilization by livestock is varied seasonally due to forage availability, or to diet selection of livestock. Reliable data illustrating the distribution of forage utilization of the landscape can help in determining stocking rates or application of appropriate behavioral methodologies for redistribution of livestock. Due to limited rangeland accessible for livestock grazing in Israel as compared to vast rangelands in the United States, range management in Israel has the challenge of pursuing techniques that incorporate more detailed methodologies which result in gaining more precise estimates of utilization of rangeland resources by livestock. Determining reliability of data obtained from pedometer devices alone or in conjunction with data obtained from GPS to predict actual times of consumption for sheep grazing is associated with objectives of this study.

MATERIALS AND METHODS

Study area

The study was conducted at the Lehavim LTER (Long-Term Ecological Research) station (31°21'52" N, 34°49'46" E) in the northern Negev region of Israel, located about 10 km north of Beersheva (Figure 1). The climate is semi-arid Mediterranean, with mean annual precipitation of 300 mm and occurring between October and May. The terrain is hilly with average height of 370 m. The landscape is highly heterogeneous and comprises a mosaic of exposed rock, microphytic crusts, shrubs (mainly *Sarcopoterium spinosum*) and herbaceous vegetation.

Sheep herd

The sheep herd is owned by a local Israeli Bedouin family who works cooperatively with the LTER station on grazing research projects. The sheep are fat-tailed awassi, a local Israeli breed that is not highly productive, but is well adapted to desert environments. The herd that was observed in this study consisted of approximately 125 adult animals. The herd was led by a shepherd with morning grazing bouts lasting approximately 3 hours, during which the observations were made.

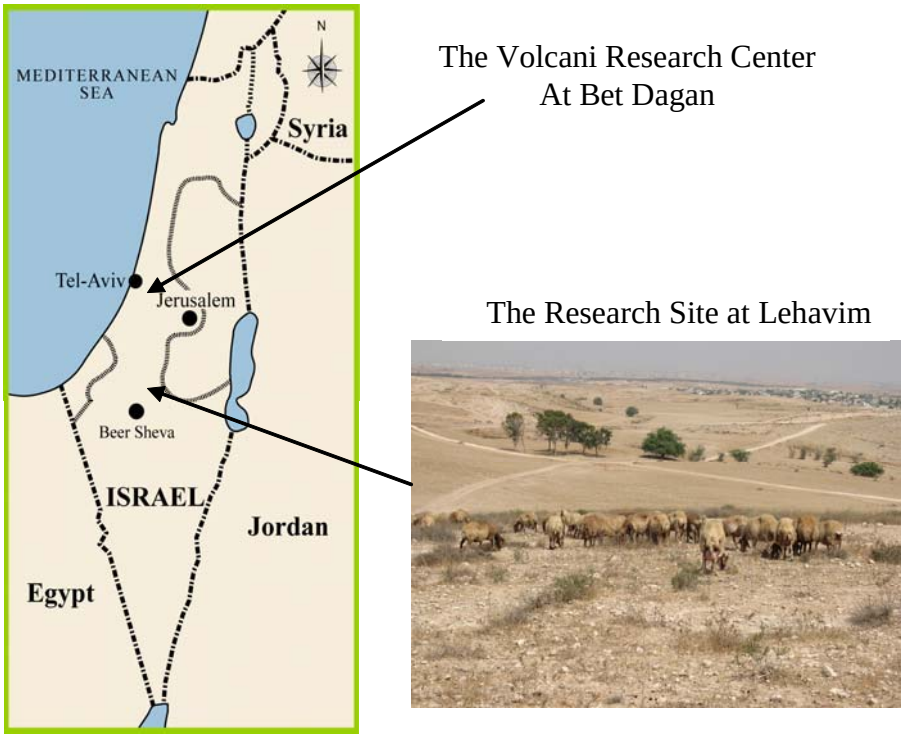


Figure 1. Map showing locations of the Volcani Center at Bet Dagan and the research site at Lehavim.

Devices and Observations

Purpose-built GPS units manufactured by Tri-Logical Technologies (Rishon le Zion, Israel) were used. These devices enable a GPS fix interval as short as one minute (versus a minimum of five minutes for Lotek GPS collars) and transmit the GPS data (position, direction and velocity) in real-time, via the GSM system, to a server

at the company headquarters. The user subsequently receives the data via email as an excel file. For small ruminants, the GPS device is configured as a back–pack, as seen in the picture on page 3. For our study, the units were configured to record a GPS fix every minute.

The Tri-Logical GPS units do not include additional sensors. On the basis of previous studies, Israeli researchers were skeptical that inter-fix distance alone would be a good predictor of animal behavior. Therefore the use of a highly sophisticated pedometer in conjunction with the GPS devices was tested. The IceTag pedometer is manufactured by IceRobotics (Roslin, Scotland, UK) and provides continuous measures of animal activity at a resolution as high as one second.

Within each time unit, activity is defined as the fraction of time that the animal is standing, the fraction of time that the animal is lying, and the fraction of time that the animal is "active". These three fractions sum to unity. In addition, the device gives the number of steps taken during the time interval.

On each observation day, and prior to the herd being led out of the central corral, a Tri-Logical GPS back-pack and an IceTag pedometer were installed on each of three randomly selected sheep. The IceTag pedometer was secured to the animal's foreleg, midway between the knee and pastern joints on the lower shank (see picture on page 3).

From the time the herd was led out of the central corral by the accompanying shepherd, one or two observers followed the herd and recorded the behavioral timeline of whichever of the three focal animals could be viewed clearly. Observations commenced at about 0800 h and terminated approximately three hours later when the sheep were brought to a watering point at about 1100 h. Observational data was documented as: standing (without grazing); standing grazing; walking (without grazing); walking grazing; and lying. Animal activity was recorded as unknown for periods during which none of the animals could be viewed clearly. The transitional resolution of the recorded behaviors was 20 seconds, meaning that a change in behavior was only recorded if it persisted for at least 20 seconds. Observations were conducted once a week for four weeks, two weeks having two observers available for data collection, totaling approximately 18 hours of animal observations.

A period of counting steps for 2 minute intervals, for each animal, was also accomplished during 3 of the sessions to test the accuracy of the pedometer device in step count measurements. Animal activity was recorded as unknown for these periods.

RESULTS

Preliminary results of observational data during the dates of July 25 through August 15, 2007, for the average time budget of activities of sheep across periods of 3-hour morning grazing bouts were observed as follows (mean ± SE): 13.3 ± 3.4, 36.7 ± 2.8, 23.7 ± 2.4 and 26.0 ± 1.0 % for standing, standing grazing, walking grazing and walking, respectively (Table 1).

Table 1. Time budgets of sheep across observation periods (as a percent of total time at pasture) at the Lehavim LTER research site. Units for activities, mean and standard error (SE) are given in percent.

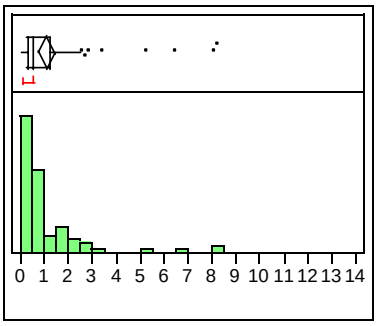
	Activity			
Observation Period	Standing	Standing Grazing	Walking Grazing	Walking
1	11.4	35.7	28.2	23.4
2	27.0	27.6	15.7	29.7
3	19.3	38.7	17.7	24.2
4	9.2	33.6	30.0	27.2
5	5.2	48.2	22.9	23.8
6	7.5	36.4	27.7	27.7
Mean	13.3	36.7	23.7	26.0
SE	3.4	2.8	2.4	1.0

The behavioral timeline of the observed animals was comprised of numerous transitions from one activity to another. The summary statistics and frequency distributions of the duration of an activity bout are shown in Figure 2. The mean duration of an activity bout ranged from about 1 to 1.5 minutes, and the variability was high. There were relatively few instances of an activity bout lasting for more than five minutes. The distributions for the different types of activity were broadly similar. The proportion of observations lasting more than 1 minute was 26% for Walking, 28% for Standing, 42% for Standing Grazing and 51% for Walking Grazing.

An algorithm was written to examine the sensitivity of the computed time allocation to the transitional resolution. The algorithm computes a new activity variable (Act2), which is equal to the original activity column subject to a duration constraint. The rule for creating Act2 is as follows: For each combination of Date, Animal and Observer, initialize Act2 to "unknown".

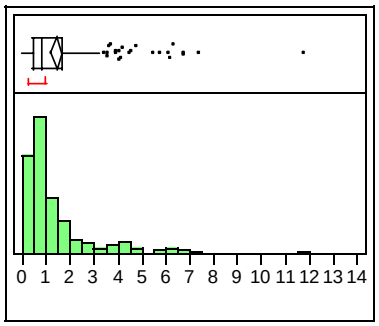
If the recorded duration of an activity is greater than a preset threshold of transitional resolution, then set Act2 to that activity. Otherwise, ignore the change in activity and set Act2 for the current data record to Act2 of the previous record.

Standing



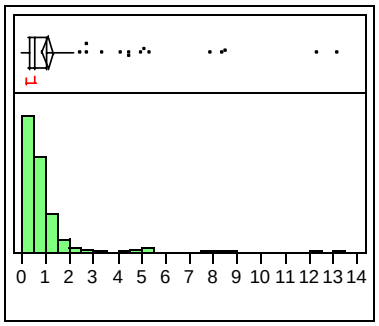
Mean	1.1390196
Std Dev	1.5450457
Std Err Mean	0.1675837
upper 95% Mean	1.4722783
lower 95% Mean	0.805761
N	85

Standing Grazing



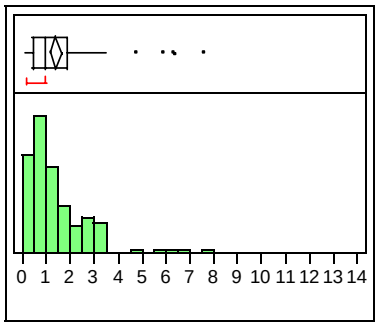
Mean	1.4564716
Std Dev	1.6713662
Std Err Mean	0.1218969
upper 95% Mean	1.6969414
lower 95% Mean	1.2160018
N	188

Walking



Mean	1.1036111
Std Dev	1.8256707
Std Err Mean	0.1360775
upper 95% Mean	1.3721335
lower 95% Mean	0.8350887
N	180

Walking Grazing



Mean	1.4399729
Std Dev	1.347915
Std Err Mean	0.1215374
upper 95% Mean	1.6805683
lower 95% Mean	1.1993775
N	123

Figure 2. Frequency distribution of the duration of the four main types of activity. Based on the field data which was recorded at the greatest transitional resolution of 20 seconds. Units are in minutes.

Threshold values from 20 seconds to over 13 minutes, which is the longest duration of any recorded activity, were examined. Figure 3 shows the response of the time devoted to each behavioral category as a function of the transitional resolution threshold.

This shows that animals transitioned from one activity to another with a high frequency, and the computed total duration of an activity started to decline from a threshold of about one minute. As the threshold was increased, a greater proportion of the observation time became defined as unknown activity.

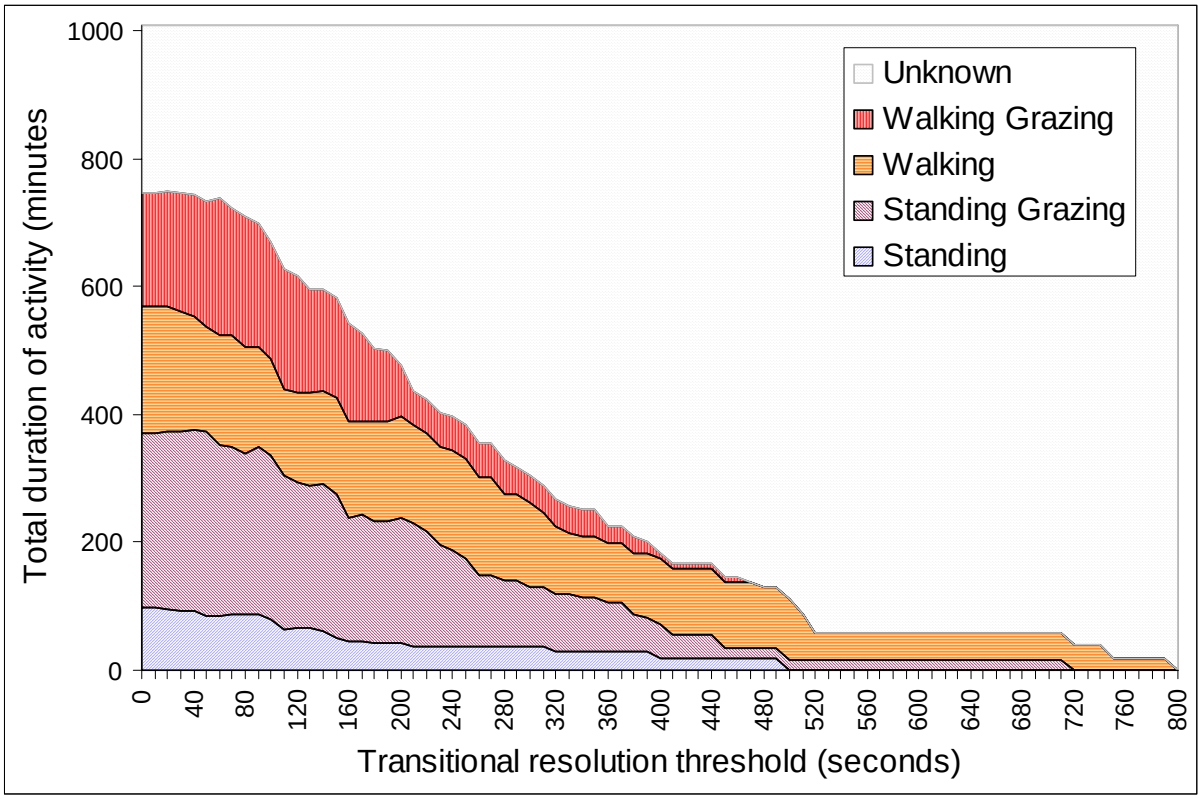


Figure 3. The response of total duration of animal activity over all observation days to the length of the transitional resolution threshold.

The data analysis regarding data obtained from IceTag devices is still under way, but results will be directed in answering the question of how well one can infer sheep activity from IceTag data. Descriptive analyses employing JMP or SAS statistical programs will be used in this process.

Preliminary results for testing the accuracy of step counts of the IceTag pedometer devices showed no significant difference between ocular observations and data obtained from the IceTag devices using a paired t-test for statistical analysis.

Further analysis of how well one can infer activity from GPS data alone and combining data from IceTag pedometer and GPS is pending. There are 3 persons cooperatively working on this project to its completion: Dr. Eugene Ungar and one of his PhD students, residing in Israel, and myself.

Upon completion of data analysis of GPS and IceTag pedometer data regarding the effectiveness of inferring sheep activities during grazing bouts, the expectation is to publish a technical note paper in a scholarly journal. Further data collection in the winter season may be necessary to thoroughly analyze the results prior to publication.

BEYOND RESEARCH

Although I have spent time in Israel, I had never frequented the area around Bet Dagan. I rented a room in a simple apartment from an Ethiopian Jewish woman in Ramla, enjoying our conversations spoken only in Hebrew. Bet Dagan is located near Rehovot, considered the agricultural hub for research in Israel, housing the Faculty of Agriculture of the Hebrew University, Jerusalem, as well as the Weizmann Institute of Science. Rishon LeZion, located within walking distance of the Volcani Center, is a community known as the first permanent settlement by Jewish immigrants. Ramla is one of several towns in Israel that has a mixed Jewish and Arab population and contains The Open House, a Jewish and Arab community center to strengthen relationships between Jews and Arabs living in Ramla. Going to the open market was another opportunity to experience the cultural diversion seen in Israel. The serenity of Shabbat was shared with old friends and concluded each hectic and engaging week at the Volcani Center. Because the weekends were limited I was unable to make a trip to Avdat, south of Beersheva where my oldest friends from Israel, several Bedouin families, live. Visiting them will be one of my first priorities on my next trip. There are several aspects of Israeli life I truly enjoy, the small corner markets, falafels and the quietness of Shabbat, in naming a few.

One of my favorite aspects of Israeli life is in using public transportation for traveling to any place in the country; life without a car is one of my dreams! My last day in Israel was spent visiting Yad Va'Shem, the Holocaust museum in Jerusalem, and reflecting on the great suffering of the Jewish people and such resulting in the rebirth the nation of Israel.

ACKNOWEDGEMENTS

I would like to express gratitude to my advisor, Dr. Derek Bailey, at New Mexico State University for encouraging me to pursue participation in the IALC Wayne Owens Peace Fellowship; Dr. Eugene D. Ungar for his nomination for the fellowship, great patience and shared expertise of data analysis; Dr. Jim P.M. Chamie and the IALC committee for accepting my application for this fellowship; and to the financial support of the IALC and the Jewish National Fund in making this cooperative research on enhancing sustainable grazing in semiarid ecosystems possible.

REFERENCE

Ungar, E.D., Henkin, Z., Gutman, M., Dolev, A., Genizi, A. and D. Ganskopp. 2005. Inference of animal activity from GPS collar data on free-ranging cattle. Rangeland Ecology and Management 58: 256-266.