GPS/GIS TECHNOLOGY IN RANGE CATTLE MANAGEMENT
(a maturing science)

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http://jornada.nmsu.edu/
“...AND THEY CAME TO A BEAUTIFUL HOUSE IN THE WOODS.”
# The Global Navigation Satellite System (GNSS)

<table>
<thead>
<tr>
<th>System</th>
<th>Acronym</th>
<th>Country</th>
<th>Coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Navstar Global Positioning System</td>
<td>GPS</td>
<td>USA</td>
<td>Global</td>
</tr>
<tr>
<td>Global Navigation Satellite System</td>
<td>GLONASS</td>
<td>Russian</td>
<td>Global</td>
</tr>
<tr>
<td>A satellite navigation system created by People’s Republic of China</td>
<td>BeiDou</td>
<td>China</td>
<td>Regional/Global</td>
</tr>
<tr>
<td>European Union and European Space Agency</td>
<td>GALILEO</td>
<td>European</td>
<td>Global</td>
</tr>
<tr>
<td>Quasi-Zenith Satellite System</td>
<td>QZSS</td>
<td>Japan</td>
<td>Regional (Asia/Oceania)</td>
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<tr>
<td>Doppler Orbitography and Radio-positioning Integrated by Satellite</td>
<td>DORIS</td>
<td>French</td>
<td>Regional</td>
</tr>
<tr>
<td>Indian Regional Navigational Satellite System</td>
<td>IRNSS</td>
<td>Indian</td>
<td>Regional</td>
</tr>
</tbody>
</table>


GPS used in farming beginning in 1990’s
A BRIEF GPS TIMELINE FOR ANIMAL TRACKING

- The US Navy used the first successful satellite navigation system in the 1960’s.
- The first wildlife tracked was the moose - 1994.
- Domestic animal tracking:
  - First – sheep - 1993
  - Second – cattle - 1997
  - Third – goats – 2000?
STUDIES USING GPS TO TRACK CATTLE

(n = 93)

See also: Fig. 1 in Swain et al. 2011. Tracking livestock using global positioning systems – are we still lost? Animal Production Science 51:167-175.
WHAT TO EXPECT FROM THIS TALK

- Background involving animal tracking
- Current tools and techniques in geospatial livestock research
- Questions yet to be addressed when using GPS and GIS with free-ranging animals
TAKE HOME LESSON

Its team,
team,
team

(Not because it allows you to blame someone else!)
EFFECTIVE TEAMS ARE KEY

Biology/ethology

Spatial statistics

Engineering/electronics
BACKGROUND
THE PLANT ANIMAL INTERFACE IS COMPLEX AND MULTIFACETED
THE CHALLENGE

“… understanding of the biological and behavioural factors influencing the spatial aspects of the foraging decisions made by animals is still in its infancy.”

RESEARCH GOALS

“… develop models of the oriented movement of animals.”


“… develop spatially explicit models of herbivore foraging behaviour …”

WHAT AFFECTS FREE-RANGING ANIMAL MOVEMENT (DISTRIBUTION)?

A new approach
WHY TRACK ANIMALS?

Disease detection and trace back

Providing a better understanding of landscape use

You can’t manage that which you can not measure

Prevent theft

Business planning

Proactive management

Hunting
SPATIAL & TEMPORAL DATA
How is the observer influencing the observation?

A 227 g ear tag

80 g GPS collar for smaller species that are not easily re-trapped
http://www.biotrack.co.uk/gps.php

A mature cow can carry a 3.2 kg (7.1 lb.) neck saddle for extended periods w/o stress – rule of thumb equipment should not exceed 3% of animal’s mass

GPS GSM Plus 5 collar for elephants

A 227 g ear tag


Implantable GPS?
On February 8, 2012 I found 355 products from 34 suppliers under the words “animal tracking GPS”

Not all GPS devices give equal performance


Position accuracy can differ among brand name collars

INSTRUMENTING & DE-INSTRUMENTING ANIMALS

Installing a GPS collar using restraint

Low stress animal handling is **THE KEY**


Installing a GPS neck-saddle using patience & “cow time”

http://www.azgfd.gov/w_c/Marked_Animals.shtml

http://repository.tamu.edu/bitstream/handle/1969.1/86125/TR334%20Environmental%20Manaqment%20of%20Grazing%20Lands%202010-08_.pdf?sequence=1
### COST OF A GPS DEVICE

**Commercially available devices (February 2012):**

- **Lotek:** $2,300 to $3,500
  - Store on board 65,000 locations, fix rate 2 min = 84 day deployment

- **Telemetry Solutions:** $2,500

**Build you own device:**

- **Clark ATS + (GPS/Iridium collar):** $835
  - Assembly time 4-5 hours over 2 to 3 days
- **Clark ATS store-on-board:** $455
- **GPS module & antenna:** $831
  - Assembly time 4-5 hours over 2 to 3 days

1993 1<sup>st</sup> time GPS loggers put on domestic ruminants (sheep) at a cost of $47,106 per unit!

**See also:** Table 3 in Davis et al. 2011. Development of a GPS Herd Activity and well-being kit (GPS HAWK) to monitor cattle behavior and the effect of sample interval on travel distance. Applied Engineering in Agriculture 27(1):143-150.
POWER REMAINS A CHALLENGE

HOW MANY ANIMALS SHOULD YOU INSTRUMENT?

As many as you can afford!

$\text{The team}$

“There has not been sufficient research to determine the minimum number of GPS collared animals required to accurately describe average group behaviours.”
HOW FREQUENTLY SHOULD I RECORD GPS FIXES?

In general --- the longer the sample interval the less useful will be the data for understanding social processes; furthermore, spatial relationships should determine sample interval.

CHALLENGES WHEN USING GPS

- Using GPS devices when they are not needed
- High initial equipment cost
- Frequent equipment failures (range 5% to >50%)
- Inappropriate number of instrumented animals can result in poor statistical inference
- Removing ethologists from the field
- Scale differences between landscape & animal

FACTORS THAT MAY AFFECT ERROR

- Vegetation cover
- Topography
- Atmospheric conditions
- As patch size decreases GPS fix rate must increase
- Data sets may be larger than software can handle
PUTTING TRACKING IN CONTEXT
“Frequently a picture is worth a 1000 words”
WHAT IS A GEOGRAPHICAL INFORMATION SYSTEM (GIS)?

Adapted from: http://egsc.usgs.gov/isb/pubs/gis_poster/
A WORD ABOUT SATELLITE IMAGERY RESOLUTION

- Spatial ------ 0.3 m to > 1000 m
- Temporal -- < 24 hours to > 16 days
- Spectral ---- 3 bands to 220 bands
SPECTRAL RESOLUTION FOR SATELLITE SENSORS

http://www.satimagingcorp.com/satellitesensors/rapideye.html
### Satellite Image Resolution

<table>
<thead>
<tr>
<th>Satellite</th>
<th>Number of bands at Nadir(^1)</th>
<th>Resolution (meters)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>CARTOSAT - 1</td>
<td>Visible region</td>
<td>2.5</td>
<td><a href="http://www.isro.org/satellites/cartosat-1.aspx">http://www.isro.org/satellites/cartosat-1.aspx</a></td>
</tr>
<tr>
<td>GEOEYE -1</td>
<td>5</td>
<td>0.41 to 1.65</td>
<td><a href="http://www.geoeye.com/CorpSite/">http://www.geoeye.com/CorpSite/</a></td>
</tr>
<tr>
<td>GEOEYE - 2</td>
<td>Assume 5</td>
<td>0.25(^3)</td>
<td><a href="http://www.geoeye.com/CorpSite/">http://www.geoeye.com/CorpSite/</a></td>
</tr>
<tr>
<td>IKONOS</td>
<td>5</td>
<td>0.82 to 3.2</td>
<td><a href="http://www.geoeye.com/CorpSite/">http://www.geoeye.com/CorpSite/</a></td>
</tr>
<tr>
<td>LANDSAT 7 + ETM(^2)</td>
<td>4</td>
<td>15 to 90</td>
<td><a href="http://landsat.gsfc.nasa.gov/about/landsat7.html">http://landsat.gsfc.nasa.gov/about/landsat7.html</a></td>
</tr>
<tr>
<td>PLEIADES - 1</td>
<td>5</td>
<td>0.5</td>
<td><a href="http://smsc.cnes.fr/PLEIADES/GP_systeme.htm">http://smsc.cnes.fr/PLEIADES/GP_systeme.htm</a></td>
</tr>
<tr>
<td>QUICKBIRD</td>
<td>5</td>
<td>0.61 to 2.44</td>
<td><a href="http://www.digitalglobe.com/">http://www.digitalglobe.com/</a></td>
</tr>
<tr>
<td>RAPIDEYE [Five constellation of satellites]</td>
<td>5</td>
<td>6.5</td>
<td><a href="http://www.rapideye.net/about/index.htm">http://www.rapideye.net/about/index.htm</a></td>
</tr>
<tr>
<td>SPOT - 5 [Système Pour l’Observation de la Terre]</td>
<td>5</td>
<td>2.5 to 5</td>
<td><a href="http://www.astrium-geo.com/">http://www.astrium-geo.com/</a></td>
</tr>
<tr>
<td>WORLDVIEW - 1</td>
<td>Panchromatic</td>
<td>0.55</td>
<td><a href="http://www.digitalglobe.com/">http://www.digitalglobe.com/</a></td>
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<tr>
<td>WORLDVIEW - 2</td>
<td>8</td>
<td>0.46 to 1.8</td>
<td><a href="http://www.digitalglobe.com/">http://www.digitalglobe.com/</a></td>
</tr>
</tbody>
</table>

\(^1\) The point on the celestial sphere that is located 90° directly below the observer.
\(^2\) Sensing takes place among seven bands: Aster -- Long-wave infrared or thermal IR = 8.125 to 11.650 and Landsat-7 -- Band 6 = 10.4 to 12.5 μm, Band 7 = 2.09 to 2.35 μm, and Band 8 = 0.52 to 0.9 μm.
\(^3\) Currently the highest resolution allowed by U.S. regulations is 0.5 m or 19.5 inches ground resolution.
THE ULTIMATE IN RESOLUTION

Lepton “Avenger” unmanned helicopter
< 1 mm per pixel


BAT 3 unmanned aerial system on catapult
30 to 60 mm resolution

CHALLENGES WHEN COMBINING GPS AND GIS DATA

- Spatial data are: points, lines and areas
- Animal data are initially points & lines
- No present off-the-shelf software for combining GIS and GPS data
- Shear volume of data to manage and analyze require standards


STEPS TO SUCCESSFULLY ANALYZING DATA

- Secure adequate input before beginning
- Sample size must be adequate
- Strive to keep the analysis simple
- Start with a “picture”
AN EXAMPLE
Of 132 questionnaires sent out via e-mail to colleagues in 2010 in the following 10 disciplines:

- animal scientists
- computer scientists
- computer engineers
- ecologists
- ethologists
- GIS specialists
- modelers
- range scientists
- robotic engineers
- statisticians

Only 45 were returned

Here is the interesting thing -- of the 28 suggestions 11 were suggested because of familiarity, while only 8 were suggested because they were the most robust to answer the question and 9 for other reasons.
HOW WOULD YOU ANALYZE GPS DATA TO ANSWER THE QUESTION?

Does free-ranging beef cow activity change following weaning?

SEVERAL PROPOSED METHODS

1. Paired t-test
2. Multiple regression analysis
3. Mixed-effects repeated measures ANOVA
4. Mixed-effects logistic regression
5. Association matrix
6. Discriminate analysis
7. Principal component analysis
8. Repeated measures Proc Mix in SAS
9. Non-parametric pie test
10. Functional data analysis
11. Extended time series
12. Minimum convex polygons
13. Markov transition model using a Kullback-Leibler divergence
14. Non-linear redistribution kernels (neural nets)
Location of cow 4127
March 17, 2009
1041 to 2400 hours

Legend
- Cow locations
- Fences and corral
- Weather station
- Drinking water
- Trails
- Roads
- Grid
  Cow route based on locations recorded in seconds
- 600
- 300
- 180
- 60
- 1

0 62.5 125 250 Meters

0 250 500 1,000 Feet
Location of cow 4127
March 17, 2009
1041 to 2400 hours

Legend

Cow locations
Fences and corral
Weather station
Drinking water
Trails
Roads
Grid
Cow route based on locations recorded in seconds
600
300
180
60
1

LANDFORMS
Alluvial flat
Alluvial plain reddish brown sand sheets
Alluvial plain wind-worked
Location of cow 4127
March 17, 2009
1041 to 2400 hours

Legend
- Cow locations
- Fences and corral
- Weather station
- Drinking water
- Trails
- Roads
- Grid
  Cow route based on locations recorded in seconds
- 600
- 300
- 180
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- 1

Quickbird image
May 1, 2003
“DRILLING” INTO THE DATA
ANIMATION KEY

- **Cow identification (circles)**
  - Blue = 4132
  - Turquoise/cyan = 6037
  - Fuchsia/pink = 6034
  - Red = 4130
  - Yellow/gold = 4127

- **Black wedge** indicates heading direction of neck with respect to “True North”

- **Green wedge** to right side of black wedge represents displacement of the head below horizontal (normal range 0 to -45˚)

- **Red wedge** to right side of black wedge represents displacement of the head above horizontal (normal range 0 to +20˚)

- **Red lines** of varying length and width represents a velocity vector looking ahead 15 s in time

- **Black cross** is the centroid (mean location) among the five cows at any point in time
THINGS TO CONSIDER WHEN USING GPS ELECTRONICS ON CATTLE

■ How frequently should you record data? It depends on the question being asked!
  ■ To pick up foraging --- 3 minutes or less

■ How many animals should you instrument?
  ■ Five to 10 should be the minimum

■ Combine autonomous with manual observations
  ■ Record observations at 1 minute intervals
QUESTIONS TO PONDER AS YOU RETURN HOME

- What is the question I am attempting to answer?
  - Experimental designs should always embrace how the animal “perceives” its world

- Do I have the appropriate research team in place?
  - Use reason when attempting to apply wildlife techniques to domestic livestock

- Am I using the correct equipment?
  - Be discerning when applying results from “small groups” to “large groups”

- Are data interpreted accurately and efficiently?
  - Outliers may tell us more than means
“Technique development is, therefore, likely to remain a fruitful area of research into the future.”

(Gordon, I.J. 1994. Animal-based measurement techniques for grazing ecology research: a review. Options Mediterraneennes 5:3-28.)
TAKE-HOME LESSON

The powerful synergy between range-animal science and GPS/GIS technology is rapidly shaping the discipline of free-ranging animal ecology.
The real Take-home Lesson

Ethologists!
THANK YOU ---- ARE THERE ANY QUESTIONS?

http://jornada.nmsu.edu/

Judge a person by his questions rather than his answers

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