

Remotely Wild

Newsletter of the Spatial Ecology & Telemetry Working Group

Issue 29: Summer 2013

From the Working Group Chair

Welcome to the 2013 summer edition of *Remotely Wild*, the newsletter of the Spatial Ecology & Telemetry Working Group of the Wildlife Society (SETWG). I hope you are having a productive season of field work and spatial data analyses. We have some great articles in this edition, and this year is proving to be an exciting one for the Working Group as we gear up for the annual Wildlife Society conference in Milwaukee. We'll continue to keep you up to date.

SETWG is proud to sponsor a great conference workshop this year that should have broad appeal to our membership - "*Analyses of Wildlife Spatial Behaviors & Habitat Use with Adehabitat R Packages*", organized by James Sheppard and presented by the author of *Adehabitat*, Dr. Clément Calenge (who will be flying in all the way from France). The main themes covered in this workshop will pertain to the four *adehabitat* packages for R: quantifying spatial relationships among objects, geometry manipulation and conversion, utilizing sampling tools, characterizing data at multiple scales, movement modeling and space-use estimation, and habitat selection exploration. Pre-registration is required for this workshop: Professionals – \$100, Students – \$75.

SETWG is also pleased to be sponsoring a symposium called '*Behind the Scenes of Landscape Genetics: A Focus on Methodology*' (organized by Cecilia Hennessy, Deahn Donner, Paula Marquardt, and Jacqueline Frair) and co-sponsoring with the Biometrics Working Group a symposium called '*Thinking Outside the Quadrat: Advances in Aerial Sampling to Estimate Abundance of Terrestrial Wildlife*' (organized by Richard Guenzel and Paul Lukacs). We invite submissions for other symposia and workshops proposals for the 2014 conference.

Thanks to those who submitted articles for this issue of our newsletter - and thanks to the SETWG membership for your continued support and interest in the Working Group. I hope to see you in Milwaukee!

Best regards, James Sheppard (spatialecologist@gmail.com)



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SPATIAL ECOLOGY & TELEMETRY WORKING GROUP

The Spatial Ecology and Telemetry Working Group provides an opportunity for TWS members to address issues of concern to the GIS community and to advance their own skills and understanding of GIS, remote sensing, and telemetry technologies. The Working Group functions as a clearinghouse of information and expertise in the area of GIS, remote sensing, and telemetry for The Wildlife Society Council, TWS sections and chapters, and



*2013 Student and Young Professional Travel Grants
Hurry! Application deadline
Aug. 30, 2013*

The Spatial Ecology and Telemetry working group of the Wildlife Society is soliciting applications for \$500 travel awards to attend the Wildlife Society's Annual 2013 Conference in Milwaukee. A total of three awards will be provided in the following categories:

1 Graduate Student awards: Must be a current graduate student or have graduated in 2013.

1 Undergraduate Student award: Must be a current undergraduate student or have graduated in 2013.

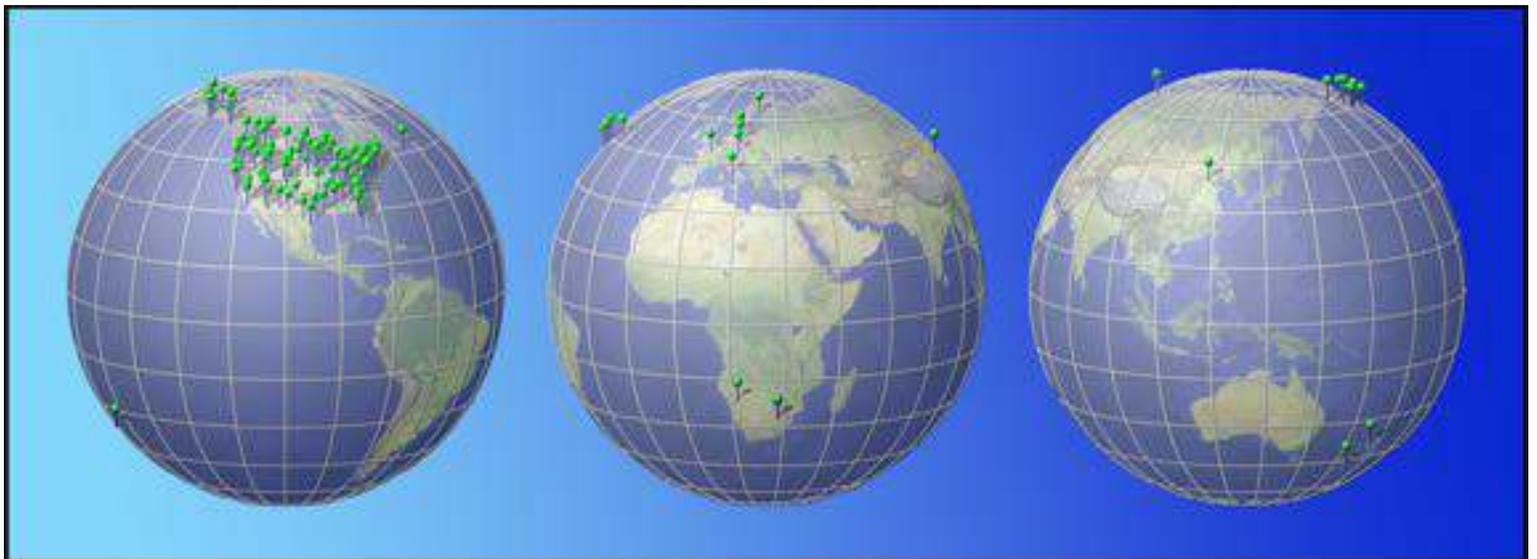
1 Young Professional award: Must have graduated from undergraduate or graduate school within the previous 2 years.

Individual applicants must be a member of the Wildlife Society at the national level. Graduate student and young professional applicants must be presenting a poster or oral presentation at the conference. Preference will be given to applicants whose research emphasizes GIS, remote sensing, or telemetry. Undergraduate applicants are not required to present but should have research interests or experience in the areas of GIS, remote sensing or telemetry. Membership in the Spatial Ecology and Telemetry working group is not a requirement for this travel grant. Award recipients are not eligible to receive a travel grant if they have been awarded a grant from

another working group or TWS committee.

To apply for the travel grant, send a copy of your presentation abstract (graduate and young professional applicants) or a description of your research interests (undergraduate applicants), a 1-page CV, and a 1-page letter stating your professional interests and why you should be considered for the award to Marci Johnson (marci_johnson@nps.gov). Make sure to mention which travel grant you are applying for.

Award recipients will be asked to write a small piece describing their research or conference experiences for our newsletter. The application deadline is August 30, 2013. Award recipients will be notified by September 10, 2013.



WHERE IN THE WORLD ARE SETWG MEMBERS...?

Symposium & Workshop Proposals

19th Annual Meeting of the WS, Milwaukee, Wisconsin (2014)

SETWG has received a proposal from the working group secretary, Paul Bartelt, for a sponsored symposium of talks for next year's annual WS conference, titled: **Spatial Approaches for Modeling Animal Habitats and Movements**. Although provisional, the following outline of this symposium proposal will be tabled at the Portland conference working group committee meeting for the membership to decide whether it merits sponsorship. The working group executive invites members to submit additional proposals for spatially-related symposia and workshops for the 2013 conference - we welcome your ideas! Please send your proposals to the Chair at: spatialecologist@gmail.com

Presentation titles, topics, and potential speakers:

1) Introduction to Spatial Data (Alisa L. Gallant, USGS/EROS Data Center)

- a) What is "spatial data" and what do they represent?
- b) What are the sources for spatial data?
- c) How can spatial data be used?
- d) What are limitations of spatial data? (resolution/scale, georeferencing, sources, cost)

2) Generating Logit Models for White-tailed Deer in the Black Hills of South Dakota (Robert W. Klaver, USGS, Iowa State University Coop Unit)

3) Using Genetic Data and Gravity Models to Estimate Animal Movements (Melanie Murphy, Univ. of Wyoming or Andrew Storfer, Washington State University)

- a) Preparing genetic data for use in spatial analyses.
- b) What are gravity models?

4) Using Physiological Data to Test Climate Change Scenarios on Animals (Warren P. Porter, Univ. of Wisconsin-Madison or Michael Kearney, Australia)

- a) Modeling physiology to identify suitable habitats and estimate corridors of endotherms.
- b) Possible climate change effects on endotherm habitats and movements.

5) Using Telemetry Data to Validate Habitat Models of Ectotherms (Paul E. Bartelt, Waldorf College)

- a) Modeling physiology to identify suitable habitats and estimate corridors of ectotherms.
- b) Using known data to validate spatial models

6) Lidar (speakers and topics pending)



SETWG Awards 2012



The Spatial Ecology and Telemetry Working Group is excited to announce the 2012 recipients of awards that recognize professionals in the field of GIS or Telemetry who have made significant contributions to the field of wildlife biology.

Award recipients do not need to be wildlife biologists or even involved in any environmental research or management. They only need to have written or produced something, or provided some service that has substantially improved our ability to do our job and enabled us to do things we may not have been able to do before. Although our awards do not include any kind of cash prize, they are a way for us, as a professional society, to say thank you to these individuals for the help they have given us.

All individuals listed below have been awarded Certificates of Appreciation from our working group, and sent letters thanking them for the tremendous service they have provided to our profession. Thank you to those members who nominated this year's winners - If you would like to nominate a individual or organization that you feel should be considered for recognition by SETWG we would love to hear from you. Please send all nominations to the working group awards committee chair Jeff Jenness (jeffj@jennessent.com).

Join us in congratulating the following 2012 SETWG awardees!

The package “adehabitat” for the R software

Cle'ment Calenge

(Contributions from Mathieu Basille,
Stephane Dray and Scott Fortmann-
Roe)

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Evolutive, Université Claude Bernard
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[http://cran.r-project.org/web/packages/
adehabitat/adehabitat.pdf](http://cran.r-project.org/web/packages/adehabitat/adehabitat.pdf)

The study of the relationships between animals and their environment is one of the main issues in ecology due to the lack of well-designed programs. The package “adehabitat” for the R software

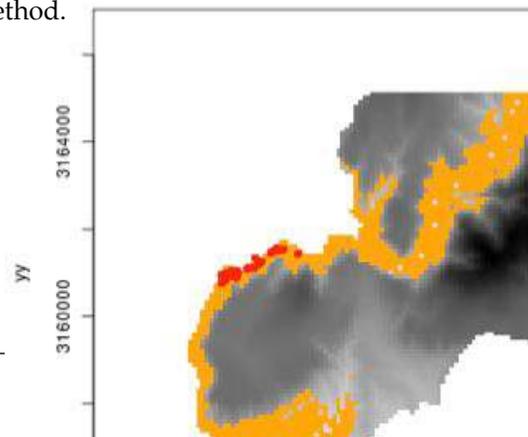
has been designed to allow the analysis of the space use by animals. The “adehabitat” package offers basic GIS functions, methods to analyze radio-tracking data and habitat selection by wildlife, and interfaces with other R packages.

It contains about 100 functions giving tools frequently used in this field of research. The graphical possibilities of this package, and the combination of the “adehabitat” functions with the powerful analysis environment provided by R allow the users to design a large diversity of analyses of the relationships between animals and their environment. These tools can be downloaded freely on the internet.

“Adehabitat” is organized in four main parts: (i) management of raster maps, (ii) habitat selection/ecological niche analysis, (iii) home range estimation and (iv) analysis of animals trajectories.

Several functions allow the computation of selection ratios, compositional analysis, K-select analysis or Ecological Niche Factor Analysis. Habitat suitability maps can be computed using Mahalanobis distances, the DOMAIN algorithm, or the ENFA. Resource selection functions may also be fitted.

“Adehabitat” also includes several tools suitable for the analysis of radio-tracking data. Home range estimators include the minimum convex polygon, the kernel estimator, the nearest neighbor convex hull, or the grid method.





SETWG Awards 2012



FRAGSTATS: spatial pattern analysis program for quantifying landscape structure.

Kevin McGarigal & Barbara J Marks

(Contributions from Eduard Ene, Sam Cushman and Maile Neel)

Oregon State University/University of Massachusetts

<http://www.umass.edu/landeco/research/fragstats/fragstats.html>

FRAGSTATS is a spatial pattern analysis program for categorical maps representing the landscape mosaic model of landscape structure. The landscape subject to analysis is user-defined and can represent any spatial phenomenon.

FRAGSTATS quantifies the areal extent and spatial distribution of patches (that is, polygons on a map coverage) within a landscape; the user must establish a sound basis for defining and scaling the landscape (including the extent and grain of the landscape) and the scheme by which patches within the landscape are classified and delineated

FRAGSTATS offers a comprehensive choice of landscape metrics and was designed to be as versatile as possible. The program is almost completely automated and thus requires little technical training.

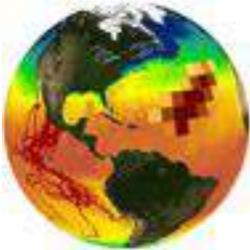
Recently, the program was upgraded to accommodate ArcGIS10 (version 3.4).

The latest release (version 4) reflects a major revamping of the software, with a completely redesigned architecture intended to support the addition of cell-level metrics and surface pattern metrics, among other things.

Version 4.0 is a stand-alone program written in Microsoft Visual C++ for use in the Windows Operating environment. It accepts raster images in a variety of formats, including Arc Grid, ASCII, and 8-, 16- or 32-bit BINARY image files.



Marine Geospatial Ecology Tools (MGET)



Jason J. Roberts, Benjamin D. Best, Daniel C. Dunn, Eric A. Treml, Patrick N. Halpin, Rob Schick & Andre Boustany.

Marine Geospatial Ecology Laboratory, Nicholas School of the Environment, Duke University &

The University of Queensland, School of Biological Sciences

<http://code.env.duke.edu/projects/mget>

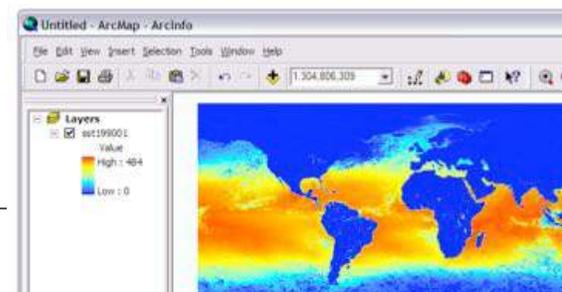
Marine Geospatial Ecology Tools (MGET), also known as the GeoEco Python package, is an open source geoprocessing toolbox designed for coastal and marine researchers and GIS analysts who work with spatially-explicit ecological and oceanographic data in scientific or management workflows.

Internally, MGET integrates Python, R, MATLAB, and C++, bringing the power of these specialized platforms to tool developers without requiring developers to orchestrate the interoperability between them.

MGET includes over 300 tools useful for a variety of tasks, such as downloading

popular oceanographic datasets in GIS-compatible formats, identifying fronts and eddies in satellite images, building statistical habitat models from species observations and creating habitat maps, modeling biological connectivity by simulating hydrodynamic larval dispersal, and building grids that summarize fishing effort, CPUE and other statistics.

Currently under development are tools for analyzing connectivity networks, for estimating fishing effort when no effort data are available, for predicting hard bottom habitat from coarse grain bathymetry, and much more.



Tracking Turtles through Changing Climate Conditions:

How El Niño / Southern Oscillations May Influence the Migrations of Leatherback Sea Turtles and What This Means for Turtle Conservation

Vanessa E. Van Zerr, Scott R. Benson, James K. Sheppard, Arthur J. Miller, Stuart A. Sandin, Jeffrey A. Seminoff, with contributions from Jim Carretta

Scripps Institution of Oceanography, University of California San Diego
National Oceanic and Atmospheric Administration, Southwest Fisheries Science Center
San Diego Zoo Institute for Conservation Research
Contact: v.vanzerr@gmail.com

The leatherback marine turtle, *Dermochelys coriacea*, is the most widely distributed and oceanic of the marine turtles, yet it is also one of the most endangered. Many Western Pacific leatherbacks undergo large-scale, trans-Pacific migrations from the Indo-Pacific to the California Current to feed on gelatinous prey blooms off the US west coast in late summer/early fall (Graham 2009; Benson et al. 2011). In the California Current Ecosystem, understanding the factors that affect the spatial ecology of leatherback marine turtles is particularly pertinent to their conservation as turtle concentrations during this time often spatially coincide with fisheries operations.

Bycatch in one of these fisheries, the California/Oregon drift gillnet fishery for swordfish and thresher shark, is a major source of adult leatherback mortality (Carretta et al. 2004). One factor that affects the spatial ecology of many organisms in the California Current is inter-annual climate variability (Menge et al. 2011). We investigated how the El Niño/Southern Oscillation (ENSO), one of the most important sources of inter-annual climate variability, affects the migrations of Western Pacific leatherbacks as they depart the California Current Ecosystem in September. Furthermore, this research provides insight into potential adaptive management measures that can be implemented to minimize seasonal leatherback bycatch while maintaining some of the current operations of the CA/OR drift gillnet fishery.

Azimuths and Geodesic Curves

The effects of the El Niño/Southern Oscillation (ENSO) can be seen in oceanic and weather fluctuations around the globe, affecting how organisms interact with their environment (Chang and Zebiak 2003). There are three main ENSO phases: the neutral phase (normal oceanic conditions), the positive phase (atypically warm conditions, “El Niño”), and the negative phase (atypically cool conditions, “La Niña”).

Leatherback marine turtles were tracked via satellite telemetry using Service Argos. Details of tracking and the methods of platform animal attachment are available in Benson et al. (2011). 41 satellite tracked leatherback marine turtles tagged near Monterey Bay, CA from 2000-2011 were used in this study. Filters were applied to Argos satellite telemetry data to remove erroneous fixes using the Douglas-Argos Filter available online (Wikelski and Kays 2013).

Values from the Multivariate ENSO Index (MEI) were used to assign ENSO phase for analysis (NOAA ESRL 2013). All monthly MEI values ≥ 0.8 standard deviations were assigned as positive phase months, all monthly MEI values ≤ -0.8 standard deviations were assigned as negative phase months, and all monthly MEI values which fell in between were assigned as neutral phase months. Analyses were conducted in R 3.0.0 and maps generated in ArcGIS 10.0.0 (R Core Team 2013). Using each animal’s monthly mean location, each animal’s mean bearing and distance traveled from Monterey Bay, CA was calculated for the month of September using great circle trigonometry. September was chosen as it is when the animals used in this analysis were tagged and began their migration out of the California Current. Kruskal-Wallis tests and Nemenyi-Damico-Wolfe-Dunn post-tests were run comparing each animal’s mean bearing and mean distance traveled in September to their corresponding monthly ENSO phase: positive (n=8 turtles), negative (n=4 turtles), and neutral (n=24 turtles).

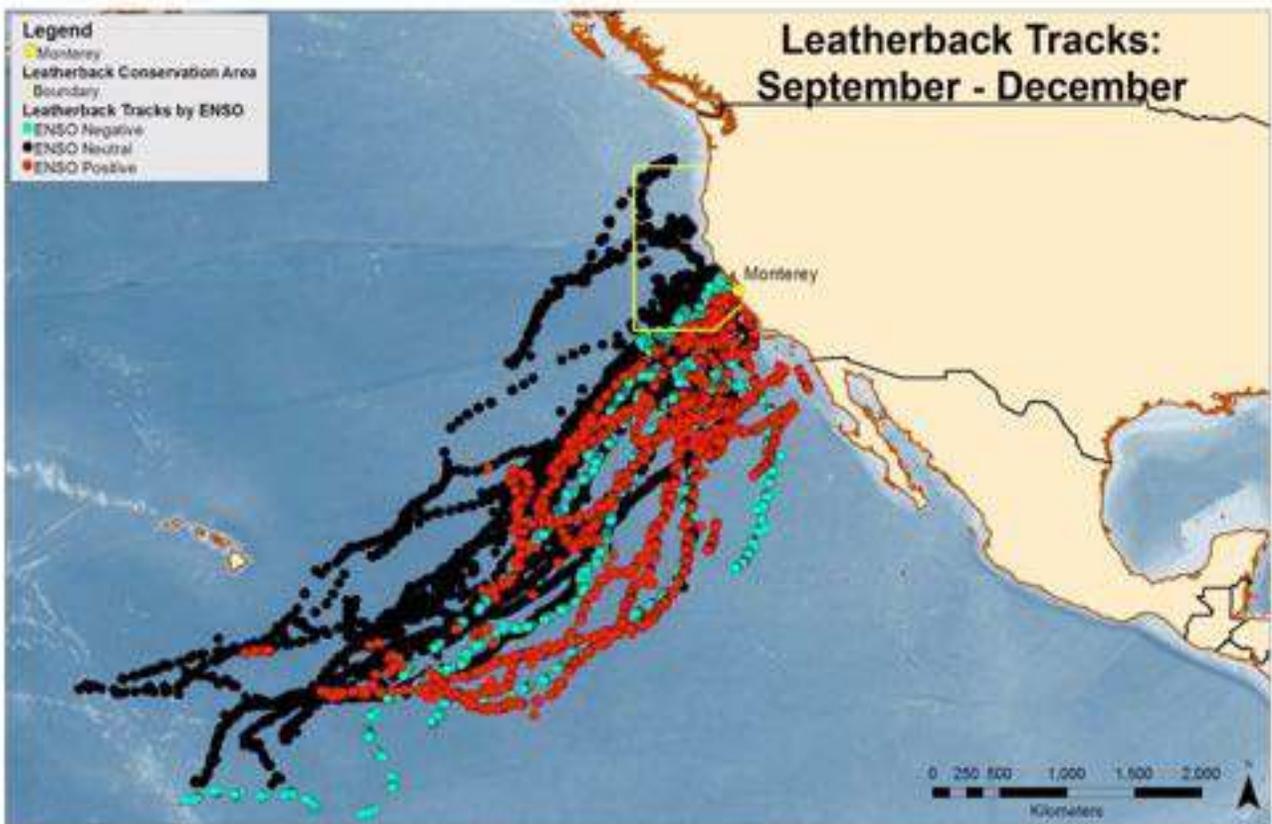


Figure 1. Tracks of satellite tagged leatherback marine turtles departing the California Current from September to December during the three phases of El Niño/Southern Oscillations. Tracks during positive (warm) phases are displayed in red, tracks during negative (cold) phases are displayed in blue, and tracks during neutral phases (normal conditions) are displayed in black. The boundary of the Leatherback Conservation Area is displayed in yellow.

Graphically Representing Directional Data

Our results demonstrate that during ENSO positive phases, there is a southward bias to Western Pacific leatherback tracks as they depart the California Current. Mapping leatherback departures shows that animals in all three groups start in September near Monterey Bay, CA (their tagging site), and then most travel progressively southwest to lower latitudes by December. However, when plotting tracks by ENSO phase, it appears that animals departing during warm and cold phase months are moving farther south than turtles departing during neutral months (Figure 1).

Analyzing September departures reveals that leatherbacks departing the California Current in ENSO positive phase Septembers bear farther south than do turtles departing during negative or neutral phase Septembers (Figure 2). Furthermore, turtles departing during ENSO positive phase Septembers also travel a greater distance southwest than do turtles departing during cool phase Septembers (Figure 2).

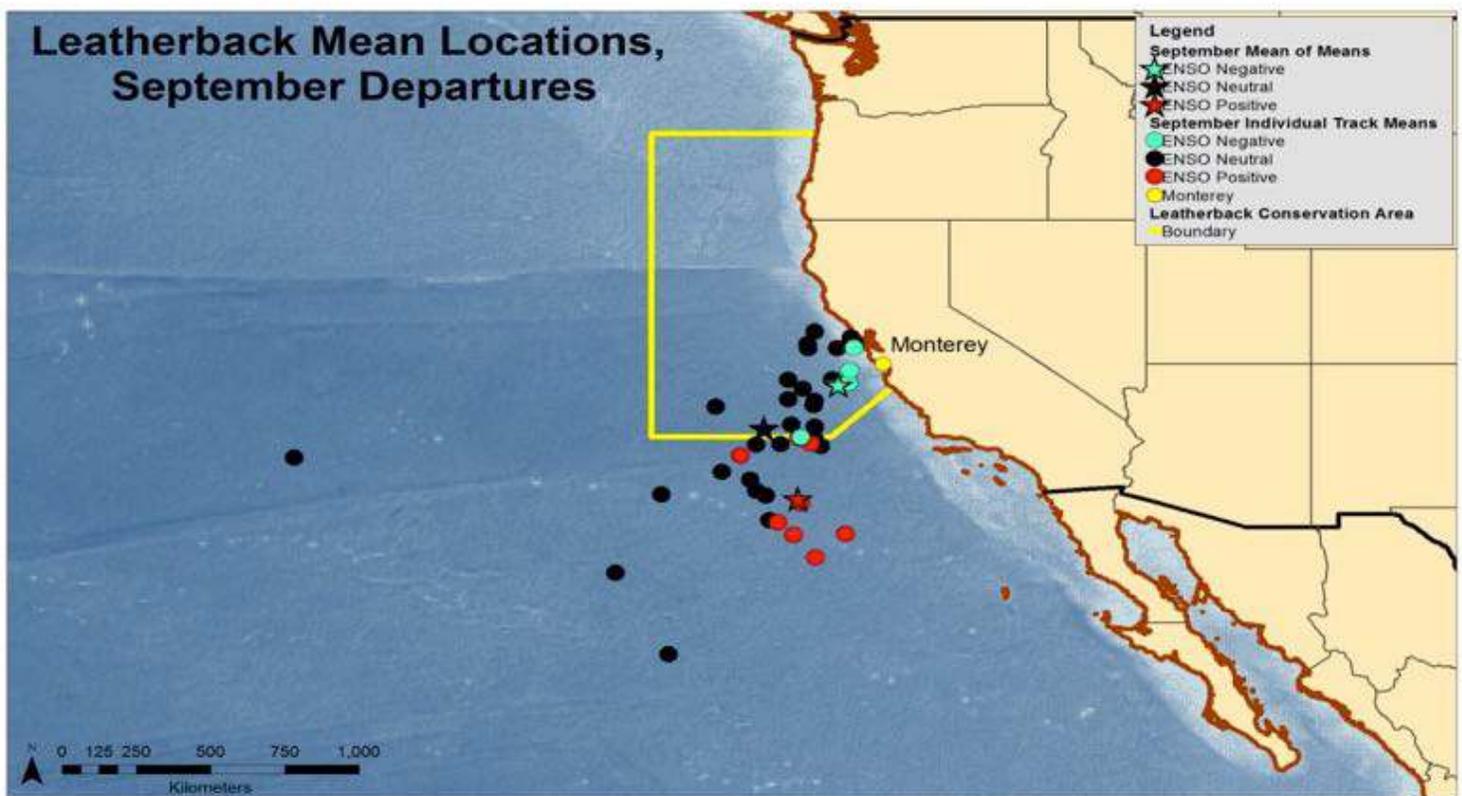
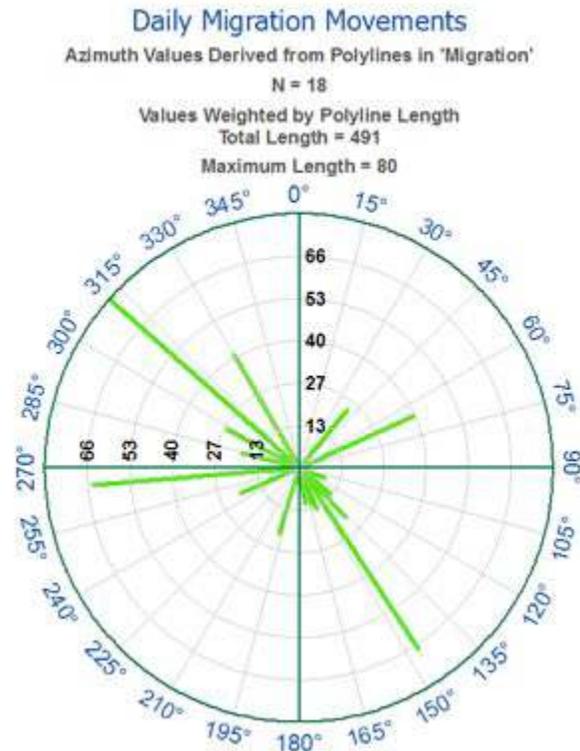


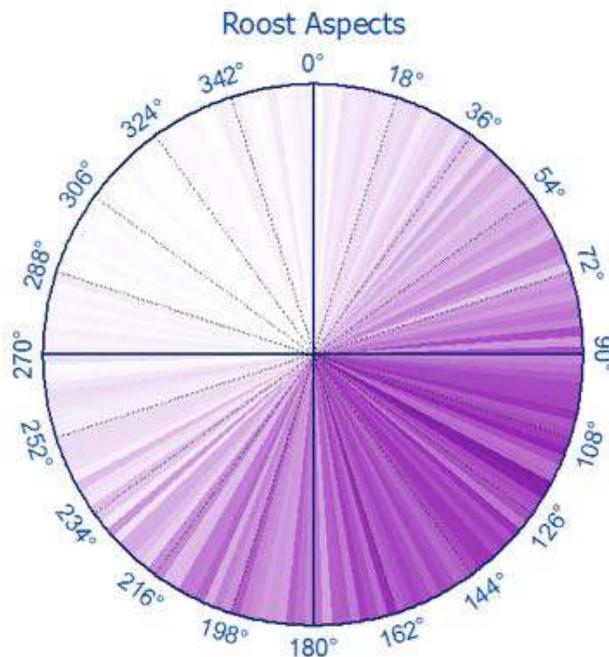
Figure 2. Map of individual turtle track means plotted by ENSO phase for the month of September. Red dots represent turtles during positive (warm) ENSO phases. Blue dots indicate turtles during negative (cold) ENSO phases. Black dots represent turtles during neutral ENSO phases. Stars represent the mean location for all turtles during each ENSO phase.

Why leatherbacks bear farther southwest during these warm periods is unknown. Potential reasons could be that turtles are tracking convergence patterns that aggregate prey, turtles are following certain oceanographic conditions, or turtles are tracking conditions that may cue either returning to the California Current for further feeding or cue embarking on a trans-Pacific migration to nesting grounds. Further research into these potential explanations is recommended.

Although leatherback bycatch is a rare event, when it does occur, it can have a significant impact on the population (NOAA NMFS 2000). Because of this, the National Marine Fisheries Service (NMFS) implemented the Leatherback Conservation Area (LCA) in 2001 (NOAA NMFS 2001; Figure 3A). The LCA is an annual time-area closure from August 15 - November 15 for the CA/OR drift gillnet fishery in order to reduce leatherback bycatch. The initial NMFS biological opinion recommended the LCA be bounded by the region connecting Point Conception, CA to the Oregon coast as shown in Figure 3B (NOAA NMFS 2000). However, due to pressure from the drift gillnet fishing community to fish north of Point Conception, an alternative southern boundary was designed and implemented as shown in Figure 3A (NOAA NMFS 2001).



When only a few direction values need to be displayed, you can simply show the bearings in a circular plot.



Another interesting method is a pie chart-type image where the “slices” are shaded according to the proportion of the data that faces that particular direction:

Although this last method is less effective at showing the shape of the distribution as other methods, it is still an interesting style of illustration because it is so visually intuitive. In the image above, it is easy to see that the observed roost locations predominately face toward the southeast.

For those who are interested, the author has provided a free ArcGIS extension to create all the plot types illustrated above (see http://www.jennessent.com/arcgis/polar_plots.htm). Additional software tools can be found with a Google search. Fisher (1995:15-30) also discusses alternative methods for graphing circular data.

Analyzing Directional Data

Circular Statistics

Before beginning this section, I want to emphasize two important points that people very often make mistakes with:

- 1) **Do not calculate the mean direction using the arithmetic mean!** This is especially frustrating because the arithmetic mean is sometimes correct and sometimes wildly incorrect. For example, the mean direction of 90° and 180° is 135° , which coincidentally is equal to the arithmetic mean. But what is the mean direction of 359° and 1° ? They are both pointing almost due north ($\pm 1^\circ$), and clearly the true mean direction is exactly due north. However, the arithmetic mean gives us 180° , which is due *south* and exactly the opposite of the correct answer. The correct way to calculate the mean direction is described below.
- 2) **If you apply a Sine or Cosine transformation, make sure to convert the values to radians first!** Most analytical software and programming languages have sine and cosine functions, but these functions usually assume the values are in *radians*, not *degrees*. There are exactly 2π (~ 6.28) radians in a circle. This means that the software will assume that a difference of 3.14 (i.e. π) units is equivalent to going halfway around the circle. If your data are in degrees, then the software will interpret a change in 2° to be roughly equivalent to going a third of the way around the circle. Fortunately it is easy to convert to radians using the following formula:

It is possible that your software has a function that allows you to calculate sines and cosines from degrees (many calculators do), but even in this case you must remember to set the switch correctly.



Fortunately there are well-established methods available for analyzing circular or periodic data such as movement

Mean Direction and Mean Resultant Length

Where: θ = Direction in Radians

$$C = \sum_{i=1}^n \cos \theta_i \quad S = \sum_{i=1}^n \sin \theta_i \quad R^2 = C^2 + S^2$$

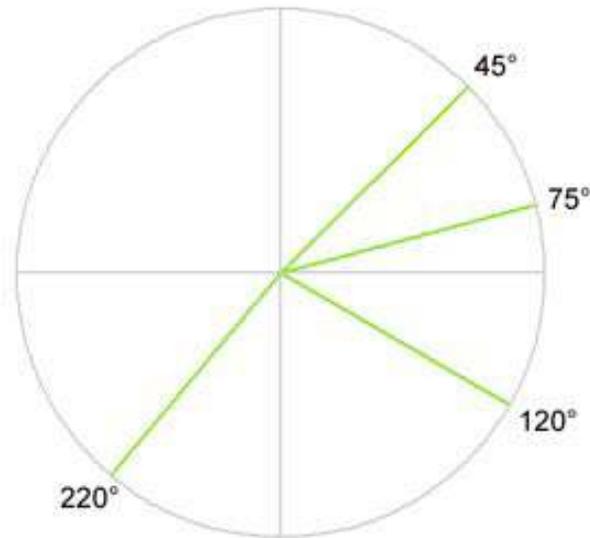
$$\text{Mean Direction: } \bar{\theta} = \begin{cases} \tan^{-1}(S/C) & S > 0, C > 0 \\ \tan^{-1}(S/C) + \pi & C < 0 \\ \tan^{-1}(S/C) + 2\pi & S < 0, C > 0 \\ \pi/2 & S > 0, C = 0 \\ -\pi/2 & S < 0, C = 0 \end{cases}$$

$$\text{Resultant Length: } R = \sqrt{R^2}$$

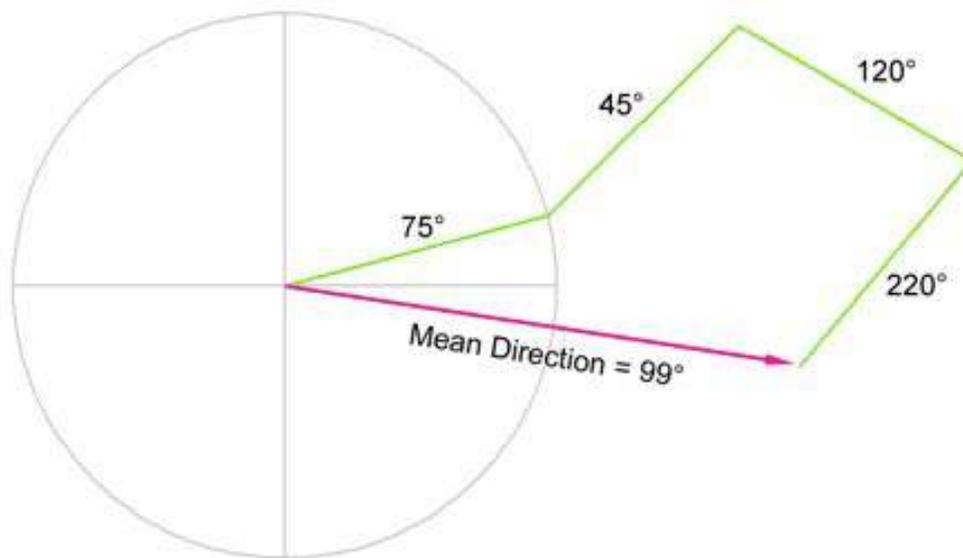
$$\text{Mean Resultant Length: } \bar{R} = \frac{R}{n}$$

The equations for mean direction look a little confusing, but the logic is actually very intuitive. It is simply a process of vector addition, where each direction value is a single vector. Vector addition essentially connects all the direction vectors into a path, and the mean direction is just the direction to the last point on the path.

For example, consider a scenario with 4 direction values at 45°, 75°, 120° and 220°:

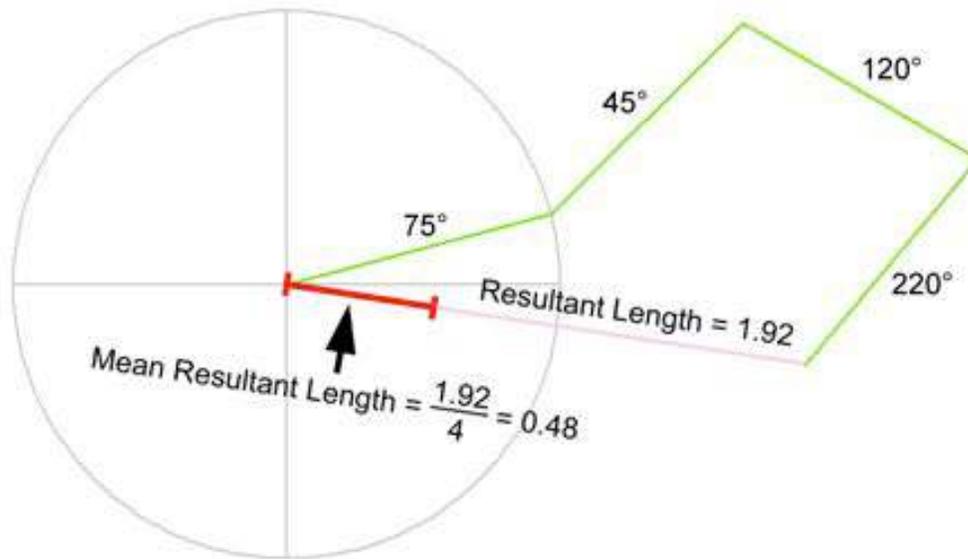


We connect the 4 bearings in a path (vector addition just adds up the ΔX and ΔY components of each vector, which is the same as treating each bearing as a segment in a path). It does not matter what order we connect the vectors in; they will always end up at the same point. The **Mean Direction** is the bearing from the start of the path to the end of the path.



On a side note, this is also the way to calculate the mean direction of an actual observed movement path. If you have a series of locations from a GPS collar on an elk, for example, and you wonder what average direction the animal moved over the day, then that average direction is simply the direction from the first GPS location of the day to the last.

The **Mean Resultant Length** is the basis for several values of dispersion (analogous to variance or standard deviation), and is calculated as the straight-line distance from the starting point to the ending point of the path divided by the number of segments (if the segments are unit vectors, where each vector has a length of 1) or by the total length of the path if the segments have variable lengths.



Notice that the mean resultant length has a potential range of 0 to 1. If all the vectors pointed in exactly the same direction, the *resultant length* would then be equal to the total path length and the *mean resultant length* would be equal to 1. This is the scenario with the minimum possible variance or dispersion in the vectors. The more the path wanders around, the shorter both the *resultant length* and the *mean resultant length* will be. If the path ended back at the origin, then both values would be equal to 0.

Variance and Standard Deviation:

Mardia and Jupp (2000), Fisher (1995) and Batschelet (1981) describe circular statistics analogous to variance and standard deviations, based on the mean resultant length.

Circular Variance: $v = 1 - \bar{R}$ (Mardia & Jupp, Fisher)

Angular Variance: $s^2 = 2(1 - \bar{R})$ (Batschelet)

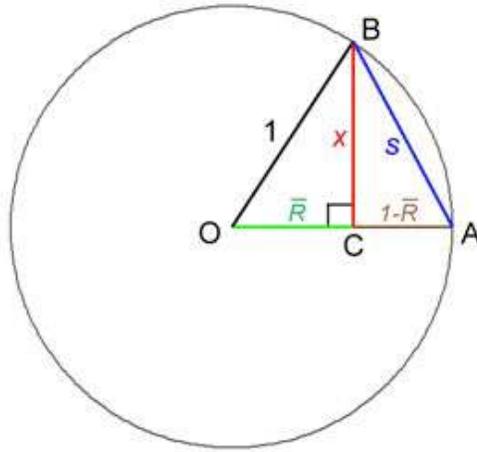
Circular Standard Deviation: $v = \sqrt{-2 \ln \bar{R}}$ (In Radians) (Mardia & Jupp, Fisher)

Angular Deviation: $s = \sqrt{s^2} = \sqrt{2(1 - \bar{R})}$ (In Radians)(Batschelet)

The *Circular Standard Deviation* and *Angular Deviation* are both in units of Radians, but these can easily be converted to Degrees.

Radians to Degrees: $Degrees = \frac{180}{\pi} (Radians)$

Batchelet points out that *circular standard deviation* and the *angular deviation* tend to be close to each other for most values of \bar{R} . However, as \bar{R} tends toward 0, *circular standard deviation* tends toward $\sqrt{2}$ while *angular deviation* tends toward a maximum value of ∞ . Batchelet, summarizing from Seyfarth and Barth (1972), presents a geometric derivation of angular deviation which also provides a visual sense of what the concept means.



Given a unit circle with Radius = 1, and with:

- Point A defined as on the circle horizontal from the Origin O
- Point C defined as \bar{R} distance along segment OA (remember that \bar{R} will always be between 0 and 1)
- Point B defined as on the circle vertical from Point C

Then s (angular deviation) is just the length of the line connecting points A and B. The angular deviation can therefore be calculated by applying the Pythagorean theorem to $\triangle BCO$ and $\triangle ABC$:

From the Pythagorean Theorem on $\triangle BCO$:

$$x^2 + \bar{R}^2 = 1^2$$

$$\therefore x^2 = 1 - \bar{R}^2$$

From the Pythagorean Theorem on $\triangle ABC$:

$$s^2 = (1 - \bar{R})^2 + x^2$$

Substituting for x :

$$\begin{aligned} s^2 &= (1 - \bar{R})^2 + (1 - \bar{R}^2) \\ &= (1 - \bar{R})(1 - \bar{R}) + 1 - \bar{R}^2 \\ &= 1 - 2\bar{R} + \bar{R}^2 + 1 - \bar{R}^2 \\ &= 2 - 2\bar{R} \\ &= 2(1 - \bar{R}) \\ \therefore s &= \sqrt{2(1 - \bar{R})} \end{aligned}$$

Based on this illustration, it is easy to see that $s = 0$ when $\bar{R} = 1$, and that $s = \sqrt{2}$ when $\bar{R} = 0$

Note: A mean resultant length (\bar{R}) near 1 always implies a tightly focused set of directions, but a mean resultant length near 0 does **not** necessarily imply a high amount of variation or dispersion. All it implies is that the directions balance each other out. This can occur with a uniform distribution of directions, in which case there truly would be high dispersion. It can also occur, however, if you have a number of bearings in one direction and an equal number in the opposite direction. For example, perhaps you have a bird with distinct and separate roost and forage locations. Every day the bird travels to the forage location and then returns to the roost location. In this scenario, the bird only goes in two distinct and opposite directions (to the forage location, and then back to the roost location). The bird's movement directions are highly focused and predictable, but the mean resultant length would be 0 and consequently the variance would be high. As with most situations, plotting the distribution of the data is a good way to understand what is really happening.

Just as with standard statistics, there are a number of circular distributions and sophisticated analytical techniques available. These go beyond the scope of this newsletter article, but please refer to Jammalamadaka and SenGupta (2001), Mardia and Jupp (2000), Zar (1999; see especially ch. 26 and 27), Fisher (1995) and Batschelet (1981) for some good texts on circular statistics, distributions (i.e. the Fisher, Von Mises and Wrapped Normal distributions), circular hypothesis testing and other analytical techniques. There is also a good circular statistical package for R, originally based on Jammalamadaka and SenGupta's text. As of June, 2012, the manual for this package can be viewed at <http://cran.wustl.edu/web/packages/circular/circular.pdf>.

Other Methods to Analyze Directional Data

If we want to include direction as one of several independent predictor variables in a traditional statistical analysis, then we must transform the value into something approaching a linear measure. There are a few straightforward ways to do this, although any transformation will probably violate some of the assumptions of most traditional statistical tests.

Classification of Aspect Values

Probably the easiest transformation is to simply group your direction values into general and intuitive ranges (for example, "N" = 315 – 45, "E" = 45 – 135, "S" = 135 – 225, and "W" = 225 - 315), creating a categorical dataset which may be appropriate for some analyses.

Deviations from a Bearing

A simple and basic transformation is to convert your direction values into deviations from a direction of interest. For example, if you felt that the object of your study was likely to be affected by the north- vs. south-facing aspect phenomenon, then you might define your direction values in terms of "Deviation from North" where each value would reflect the distance, in degrees, from due North. Your full set of transformed values would range from 0 to 180 (see figure below). This option has the advantage of maintaining a constant interval between units, such that the difference in direction between 0 and 1 degree is the same as the difference between 90 and 91 degrees.

Sine and Cosine Transformations

Aspect values are often converted to sine and cosine values, essentially decomposing them into north-south and east-west components.

Remember to convert your direction values to radians before doing this transformation! Sine values range from -1 (at due west) to 1 (at due east), while cosine values range from -1 (at due south) to 1 (at due north). Note that this method does not maintain a constant interval between units. The sine and cosine values change by a variable amount depending on the direction, such that a change in sine corresponding to a change of 1 degree = 0.00015 when going from 90 to 91 degrees, but increases by more than 2 orders of magnitude to 0.017 when going from 180 to 181 degrees. This issue may be important in your statistical analysis if your method assumes that your data are interval-level.

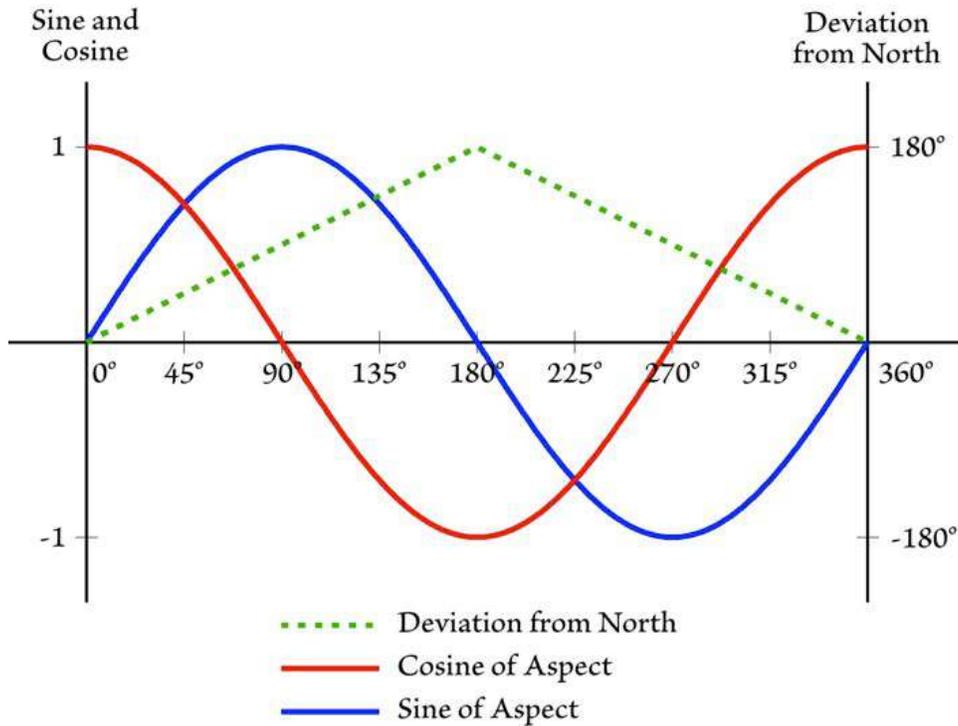
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Trimble and Weitzman (1956) and Beers et al. (1966) suggest an

interesting alternative combining two of the approaches above, rescaling aspect values based on an optimum bearing (135° for Trimble & Weitzman, and a general equation for any aspect of interest for Beers et al.) then taking the sine of the rescaled values, then adding 1, which they put to extensive use in site productivity research for

$$\begin{aligned}
 A' &= \text{Transformed Aspect Code} \\
 &= \sin \left[A + (90 - A_{Max}) \right] + 1 \\
 &= \cos(A_{Max} - A) + 1
 \end{aligned}$$

Where:

A_{Max} = The aspect which is to be assigned the highest numerical value on the transform scale

Special Considerations for Aspect

How Aspect is Calculated

Aspect is calculated from the directional East-West and North-South gradients at a particular point. There are various methods for estimating these directional gradients from a 3x3 set of elevation points, but in general aspect is defined as the direction of maximum slope. Given that G = east-to-west gradient and H = north-to-south gradient, then aspect is calculated as follows:

$$\text{Mathematical Direction (in degrees)} = \text{atan2}(H, -G) \left(\frac{180}{\pi} \right)$$

The “atan2” function is a method of calculating the arctangent (\tan^{-1}) using two values (ΔX and ΔY), and it has a possible range representing a full circle ($-\pi$ to $+\pi$ radians, or -180° to $+180^\circ$). The standard arctangent function can only produce values ranging from $-\pi/2$ to $+\pi/2$, or -90° to $+90^\circ$.

$$\bar{R} + \frac{\pi}{2}$$

This atan2 function is the same one used to calculate mean direction above, and is calculated as follows:

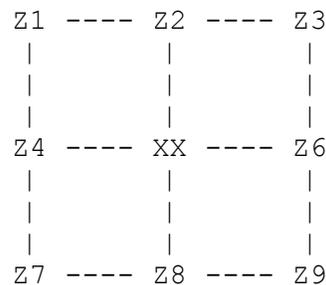
$$\text{atan2}(y,x): \bar{\theta} = \begin{cases} \tan^{-1}\left(\frac{y}{x}\right) & y > 0, x > 0 \\ \tan^{-1}\left(\frac{y}{x}\right) + \pi & y \geq 0, x < 0 \\ \tan^{-1}\left(\frac{y}{x}\right) - \pi & y < 0, x < 0 \\ \frac{\pi}{2} & y > 0, x = 0 \\ -\frac{\pi}{2} & y < 0, x = 0 \\ \text{Undefined} & y = 0, x = 0 \quad (\text{i.e. no movement}) \end{cases}$$

Mathematical direction is different than compass direction. In the mathematical polar coordinate system, 0° is equivalent to due east and polar directions increase in a counter-clockwise direction. Compass direction starts at north and increases in a clockwise direction. Therefore we must convert the mathematical direction to a compass aspect according to the following rules:

if *Mathematical Direction* > 90° then *Aspect* = (450 – Direction)

Otherwise *Aspect* = (90 – Direction)

ArcGIS uses Horn’s method (Horn 1981, Burrough and McDonnell 1998)to calculate the east-west (G) and north-south (H) gradients from a 3x3 array of elevation points. The figure below shows the 8 elevation values that are used to calculate aspect at the central cell XX (note that the formula does not use the elevation value at the central cell):



In Horn’s Method, the north-south gradient is calculated from all three columns in the 3x3 array, with the central column weighted twice as high as the two outer columns. The east-west gradient is calculated in a similar manner.

$$\text{East-West Gradient} = G = \frac{[(Z_3 + 2Z_6 + Z_9) - (Z_1 + 2Z_4 + Z_7)]}{8\Delta x}$$

$$\text{North-South Gradient} = H = \frac{[(Z_1 + 2Z_2 + Z_3) - (Z_7 + 2Z_8 + Z_9)]}{8\Delta y}$$



Is this the best method to calculate aspect?

Interestingly, Jones (1998) compared several slope and aspect algorithms on a mathematical surface in which the true exact slope and aspect at any point could be calculated. He found that Horn's method did better than most methods, but was marginally worse than a method called the 4-cell method. He then tested all methods on a true landscape DEM and found that the rankings among methods were consistent, so Horn's method still came in 2nd place.

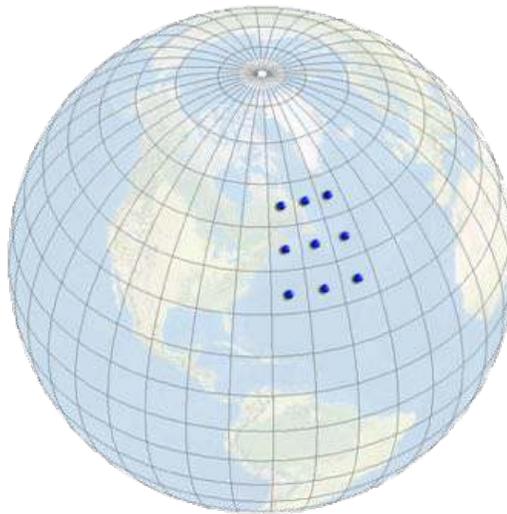
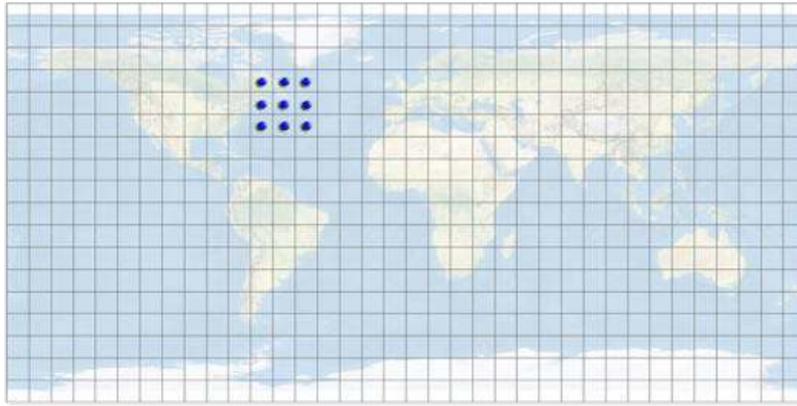
Another tidbit: Michael Hodgson (1995) published a paper using the same mathematical surface that Jones (1998) did, in which he demonstrates that the area represented by computed slope and aspect is actually larger than the raster DEM cell size. 8-cell algorithms (such as *Horn's* method) more accurately reflect values for an area approximately twice the cell size, while 4-cell algorithms (such as the *4-Cell* method) reflect an area approximately 1.6X the original cell area.

In sum, a method called the 4-cell method is simpler, slightly quicker to calculate, more precise and marginally more accurate than Horn's method.

For those who are interested, the author offers a free ArcGIS extension that will calculate slope and aspect using a variety of methods including both Horn's method and the 4-cell method (see http://www.jennessent.com/arcgis/surface_area.htm). This extension does not require Spatial Analyst.

Issues with Aspect

As a consequence of determining aspect from East-West and North-South components, aspect can be difficult to calculate from geographically-projected (latitude/longitude) data. The equations above all work for 3x3 arrays in which the elevation locations are all equally spaced along both the X- and Y-axes. However, this is not the case with latitude / longitude data. Raster cells that are square in unprojected space actually form trapezoids when viewed on the actual surface of the planet.



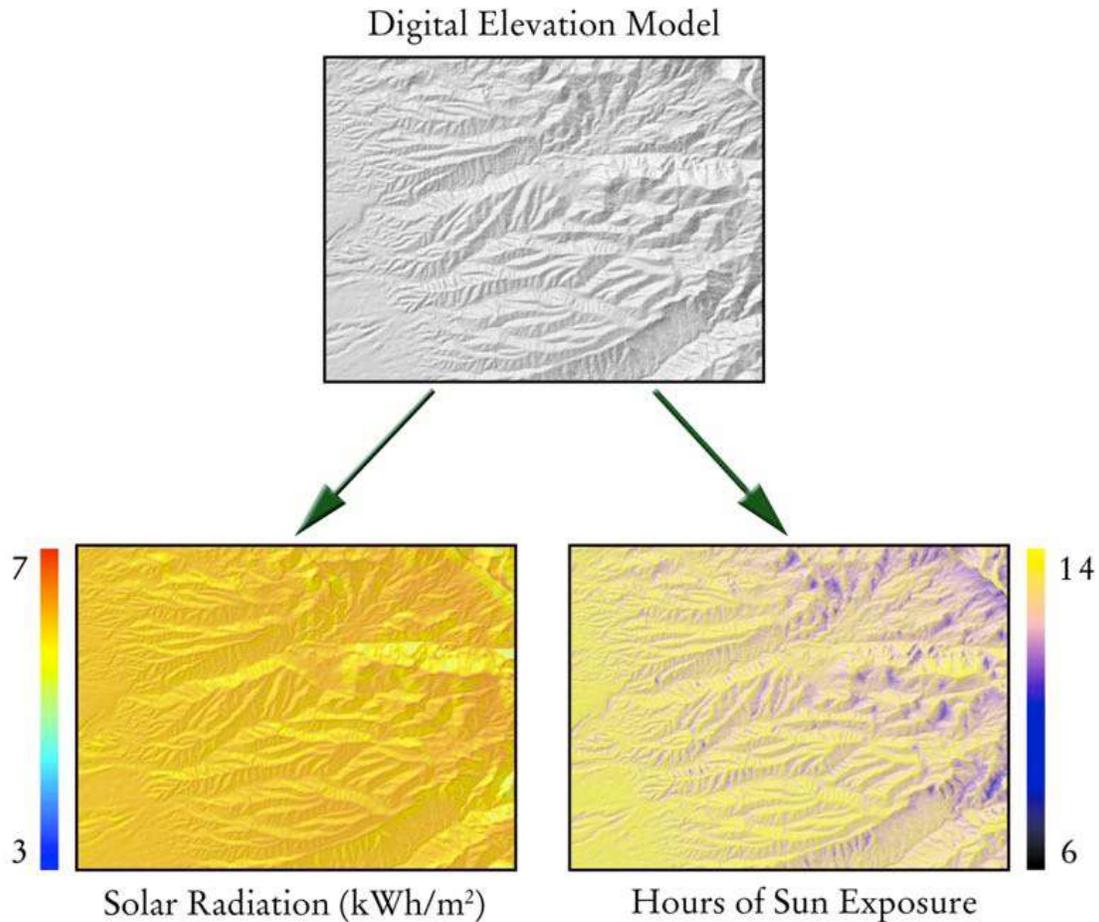
In this case, we cannot treat the cell size as a single constant value. The methods to correct for latitude/longitude data go beyond the scope of this article but are described in Jenness (2011; see especially p. 40 - 49 of the manual at <http://www.jennessent.com/downloads/DEM%20Surface%20Tools%20for%20ArcGIS.pdf>). For those who are interested, the author's free ArcGIS extension DEM Surface Tools will automatically correct for latitude/longitude data (see http://www.jennessent.com/arcgis/surface_area.htm).

Solar Insolation: An alternative to Aspect

Aspect has a well-established history in habitat analysis. It is both easy to measure and a good predictor of certain habitat characteristics. However, in some cases we are really interested in how much direct sunlight hits an area (insolation), which is a function of aspect, slope, nearby topography, landscape reflectivity and atmospheric effects, and as such may be a more important driver of habitat characteristics than aspect alone. In such cases, it may be worthwhile to estimate insolation directly rather than use aspect as a surrogate. There are a few approaches you can take:

ESRI's Solar Radiation Tool

As of version 9.2 of ArcGIS and Spatial Analyst, ESRI has included a tool in the ArcToolbox to calculate solar radiation for specific points on the landscape, or over the entire landscape.



This function incorporates both direct and diffuse radiation and shadows from nearby topography. It includes several useful options, including:

- 1) Outputs either the amount of energy hitting the ground (in Watts per Hour), or the total number of hours in which the ground is exposed to the sun.
- 2) Can be calculated for specific dates, seasons or years.
- 3) Has optional parameters where you can specify the general atmospheric conditions in your area of interest.
- 4) Has optional parameters where you can specify how intensively it examines the local topography before determining the amount of radiation hitting an area.

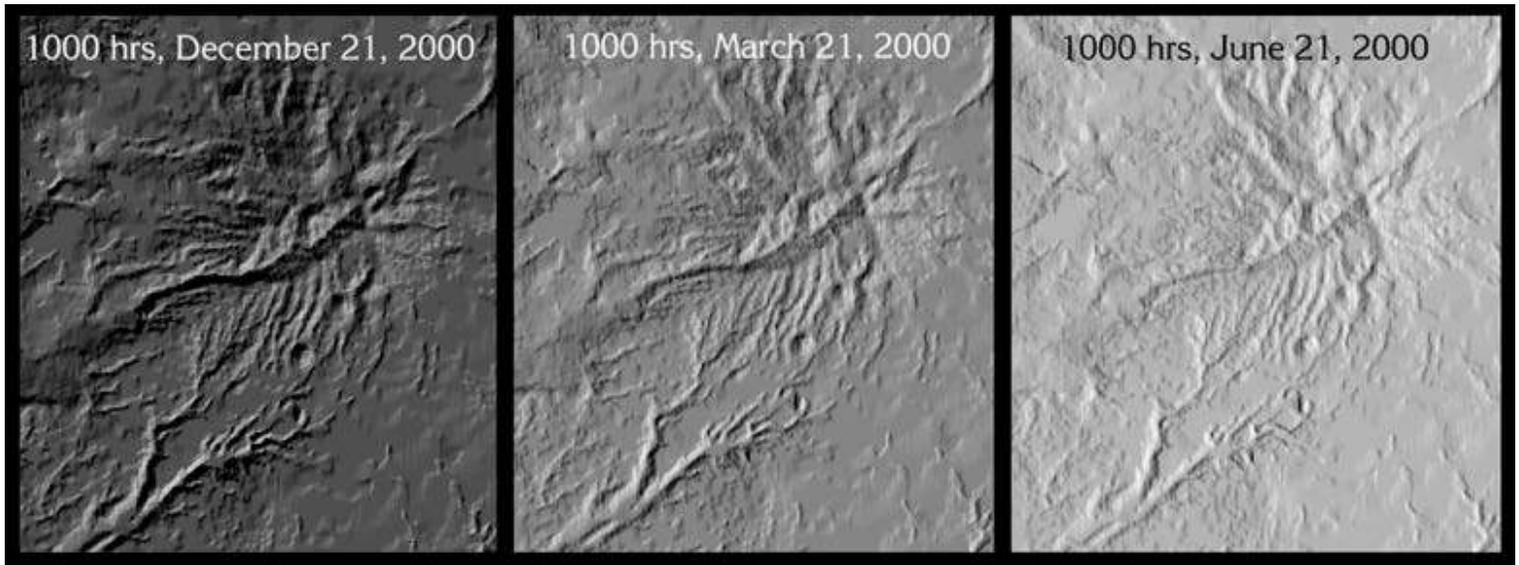
In general, this is a wonderful and exciting new tool. I have noticed two minor drawbacks to the tool:

- 1) It is slow on large grids, and on occasion I have needed to let it run for hours or days.
- 2) I do not believe that it incorporates reflectivity off the landscape. This would be hard to model, of course, and would depend on exactly how reflective your landscape is (snow reflects very differently from lava rocks, for example).

Despite these two minor drawbacks, I expect that this tool will become very valuable for habitat analysis.

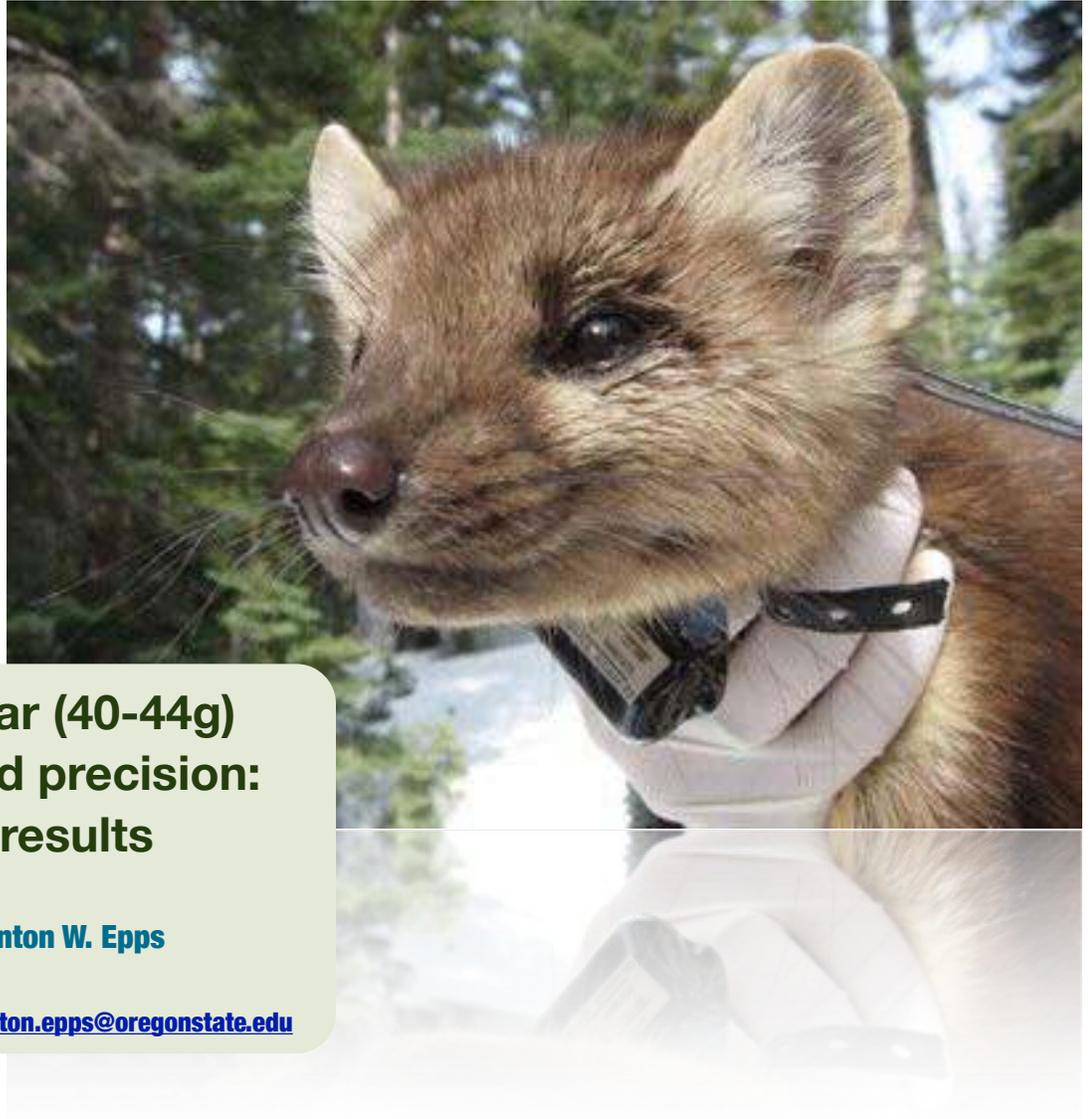
Hillshade

For those who do not have access to the Solar Analyst, you can use the hillshade function available in many GIS packages get a reasonable estimate for the relative amount of sunlight that hits the landscape at a single point in time. Values will typically range from 0 (meaning no sunlight hits the landscape) to 255 (meaning the angle of the landscape is facing the sun directly). Hillshades are difficult to calculate if your DEM is in geographic coordinates, but the author offers a free ArcGIS tool to do this (see http://www.jennessent.com/arcgis/surface_area.htm) which does not require Spatial Analyst.



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Micro-GPS collar (40-44g) effectiveness and precision: preliminary results

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Global Positioning System (GPS) collars provide an unprecedented amount of animal location data. However, GPS units are plagued with non-random data loss that can be attributed to canopy cover, terrain, animal behavior, satellite coverage, unit orientation, and other factors (D'Eon and Delparte 2005, Frair et al. 2010). Evaluation of GPS bias is necessary to better understand biological significance of data (Hebblewhite and Haydon 2010).

Lightweight GPS collars (~90g) have battery limitations, and may have additional failures (Blackie 2010). Some issues may be due to component proximity, pressure from drying epoxy, and connection fragility. Performance of lightweight GPS collars may be similar to larger models (Recio et al. 2011); however, little is known about effectiveness of miniature GPS collars (40-45g). In conjunction with a study focused on Pacific marten (*Martes caurina*) movement, we conducted stationary and movement tests with miniature GPS collars (Telemetry Solutions, Quantum 4000, Concord, CA 40-45g). We aimed to better understand GPS precision with each fix type (3, >3 satellites) and data loss in three types of habitat (complex and dense, thinned, open) at high elevation sites within Lassen National Forest, California. We used those habitat classifications to describe stands with similar structural features but that differed in vegetation type.

Fix precision was estimated by comparing the GPS collar's location to an estimated location from a GPS unit (Garmin 10X). We evaluated fix success rate (%) and fix precision in relation to habitat type, aspect, and elevation. In addition, we paired movement tests to evaluate GPS collar performance in two modes: continuous and cold start. The continuous mode retained previous ephemeris satellite data whereas in cold start, the GPS needed to acquire new satellite data prior to calculating a location. We assumed cold start mode would be similar to fixes scheduled at long intervals (>1 hour) or after satellites were lost for a prolonged period, and could be compared to a marten spending a prolonged period in an area without satellite coverage (e.g. a cavity, see Figure 1).

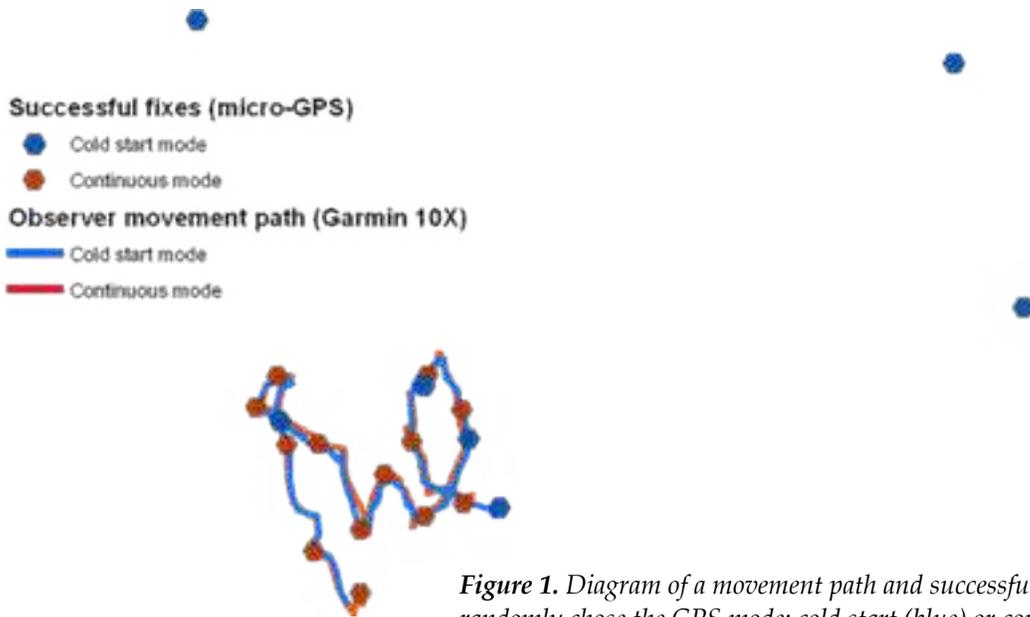


Figure 1. Diagram of a movement path and successful fixes with the micro-GPS. We randomly chose the GPS mode: cold start (blue) or continuous (red). We walked for a minimum of an hour, and returned along the same path in the alternate mode. Precision was estimated by comparing the micro-GPS fix with the track log location recorded at the same time.

Our results are tentative as we are still conducting field trials. From our current data it appears that fix success was significantly affected by the mode (continuous/ cold start) and habitat type ($R^2 = 0.31$, $P < 0.001$). However, habitat was not a predictor of fix success in continuous mode (Table 1). In cold start mode the unit is more likely to take a fix as canopy cover decreases. Following successful fixes, average precision distance from our tracklog was 28.0m (CI95%=16.0-39.9m) in 3D mode and 586.8m (CI95%=461.4-712.2m) in 2D mode. Precision was not affected by habitat type among the 2D or 3D fixes.

Miniature GPS units provide a novel opportunity to study movement of elusive small mammals (1000g), such as martens and fishers, which was impractical with previous technology. Martens and fishers are associated with dense canopy, and canopy cover is known to reduce fix success (D'Eon et al. 2002, Frair et al. 2004). Our study demonstrates retaining satellite memory was essential for fix success. Residual satellite data was most important in dense canopy with increased obstructions; see also Augustine et al. (2011). Ott and van Aarde (2010) suggested including 2D fix locations, our study suggest these fixes may misrepresent location information (Figure 2). In future analyses, we will investigate if 2D precision can be predicted by covariates (e.g. HDOP).

Table 1. Precision between cold start & continuous modes. We evaluated precision by comparing micro-GPS collar fixes (Quantum 4000) with a tracklog (Garmin 10X) with average values (m), standard errors (parentheses), and sample size (subscripts). Our track logs recorded an average of 7.4 satellites ($SE = 0.1$) in all habitat types ($n = 600$).

	Complex stands		Thinned stands		Open stands		All stand types	
	Cold Start	Continuous	Cold Start	Continuous	Cold Start	Continuous	Cold Start	Continuous
3D fix	19.5 (6.1) ₄	21.5 (2.4) ₅₆	17.8 (7.7) ₁₇	22.0 (4.6) ₉₅	30.9 (7.0) ₄₄	39.2 (19.5) ₉₂	26.7 (5.2) ₆₅	28.3 (7.6) ₂₄₃
2D fix	951.2 (73.1) ₃	239.2 (40.3) ₃₉	889.8 (191.6) ₈	536.4 (166.0) ₁₄	1311.9 (158.0) ₁₁	982.0 (227.9) ₇	1109.2 (111.5) ₂₂	395.2 (61.1) ₆₂
No fix	NA ₅₅	NA ₄₂	NA ₇₃	NA ₁₂₆	NA ₁₈	NA ₃	NA ₁₄₆	NA ₆₂

Our precision during movement tests were similar to values reported by Cargnelutti et al. (2007). Surprisingly, there was no indication that topography, elevation, or density affected precision of 3D fixes. Most of our trials were in areas with similar topology, so additional tests will be conducted during summer 2012.

We suspect that when animals rest in cavities or under the snow for extended periods (>4 hrs) the previous satellite data is lost (similar to cold start mode). Once the GPS obtains a 3D fix, it accurately represents the animal's location. Stationary tests under-correct for the probability of fix acquisition in habitats with high levels of obstruction, creating overly optimistic assessments GPS capabilities (Augustine et al. 2011). Our movement tests will provide more accurate information on GPS fix-success and precision within our study area.

Micro-GPS collars provide a substantive amount of data, despite battery limitations. Although more information is necessary to understand the limitations of our inferences, our tests suggest that 3D fixes (>3 satellites) provide acceptable precision. In the future we will assess the likelihood of the unit obtaining a successful fix in dense and topographically diverse areas.

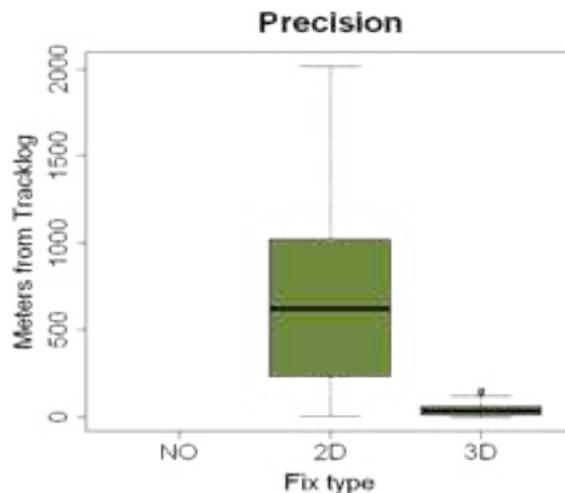


Figure 2. Median, quartiles, and outliers for precision (note the large difference in precision based on the type of fix).

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NATURAL RESOURCES COMMUNICATION WORKSHOP ANNOUNCED

The Natural Resources Communication Workshop, sponsored by the Western Section of The Wildlife Society and the Department of Recreation, Hospitality, and Parks Management at California State University-Chico, will be held at California State University, Chico from January 7-11, 2013. The week-long workshop is designed to help natural resource workers more effectively communicate with general as well as technical audiences through personal presentations using computer-generated PowerPoint images. A variety of topics are covered including selecting communication strategies for specific audiences, creating computer-generated graphics, avoiding PowerPoint presentation "pitfalls," handling difficult questions, and solving equipment problems.

The workshop's instructor is Dr. Jon Hooper, a Certified Wildlife Biologist (CWB) and longtime member of The Wildlife Society. He is a Certified Interpretive Trainer (CIT) and has taught communication workshops for over 35 years in locations around the country and holds degrees in environmental communication and wildlife ecology.

The initial deadline for applications is October 31, 2012 (Wednesday). Late applications are accepted for placement on a waiting list. The registration fee is \$789. The workshop is limited to 16 participants. The registration fee is not due until an applicant has been officially accepted into the workshop.

Applying for the workshop is easy. On letterhead, applicants should describe: (1) their current position within their agency/organization, (2) how they would use the training, (3) any special reasons why they feel they should be chosen as a participant, and (4) if they already have official agency/organization approval to attend. Applicants should include their address, phone number, fax number, and email address with their application.

Submit applications to: Dr. Jon K. Hooper, Dept. Recreation, Hospitality, and Parks Management, Calif. State University, Chico, CA 95929-0560. For more information, contact Jon by calling (530) 898-5811, faxing (530) 898-6557, or e-mailing "jhooper@csuchico.edu."

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Mapping a Critical Resource: the Habitats of Sri Lanka's Elephants

Sri Lanka, a small island nation with over 20 million inhabitants, has one of the largest remaining wild elephant populations in the world. The combined high population densities of people and elephants produce one of the highest rates of human elephant conflict, with about 50-60 people killed by elephants annually. Protected areas such as national parks and forest reserves are quickly becoming the last refuge for these animals. Habitat improvements for elephants in protected areas should be a key component of current conservation strategies to ensure the survival of increasing elephant populations.

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Things always get interesting when someone yells, "There's a monkey loose in the house!" Surprisingly for a girl from Detroit, instances like this are not all that uncommon in my life. Over the past few years I've tracked red wolves, had an alligator bite my kayak, and have been charged by fully grown bull elephant. So to have another field season begin with a macaque rifling through my kitchen is almost expected.

Currently, I am lucky enough to be working on a joint project with the Smithsonian Institution, Clemson University, and the Centre for Conservation and Research, a Sri Lankan non-profit organization, centered on elephant habitat management in Sri Lanka. The leading threats to the survival of wild Asian elephants are habitat loss and human elephant conflict (HEC) (Sukumar 1989, 2003; Fernando et al. 2005). Habitat loss is generally attributed to agricultural expansion, either through subsistence farming or broad-scale conversion of wildlife habitat into industrial plantations and agriculture (Flint 1994, Leimgruber et al. 2003; Sodhi et al. 2004; Koh & Wilcove 2008). As natural areas are increasingly being lost, HEC rates rise usually with detrimental consequences for elephant populations ranging from defense or retaliatory killings of elephants to local extinction and serious broad-scale population declines.

Sri Lanka has one of the largest remaining wild elephant populations (~5,000; Fernando pers. com.) and some of the highest levels of HEC in Asia. High human population densities (325 people per km²) result in constant demand for more agricultural and development land and produce intense HEC. As development and habitat fragmentation proceed, elephant populations will decline and increasingly be pushed into the existing protected areas.

Grassland ecosystems play a critical role in supporting elephant populations in Sri Lanka's protected areas. Udawalawe National Park (UNP) and Hurulu Reserve (HR) (Fig. 1) are examples of two parks where large elephant groups rely on grassland habitats as a primary food resource. However, these grassland ecosystems are not static and over the past decade they have been receding at UNP and HR. These declines most likely can be attributed to the lack of regular fires which results in shrub and forest regeneration. Additionally, the spread of exotic and invasive plants such as *Lantana camara* may have significantly reduced the grassland areas.

However, no systematic habitat management strategies have been developed or tested in Sri Lanka. I am assessing the extent of the remaining grassland as well as the spread of invasive species in relation to vegetative composition, fire frequency (Fig. 2), and habitat use preferences of the elephants in Udawalawe National Park and Hurulu Reserve.

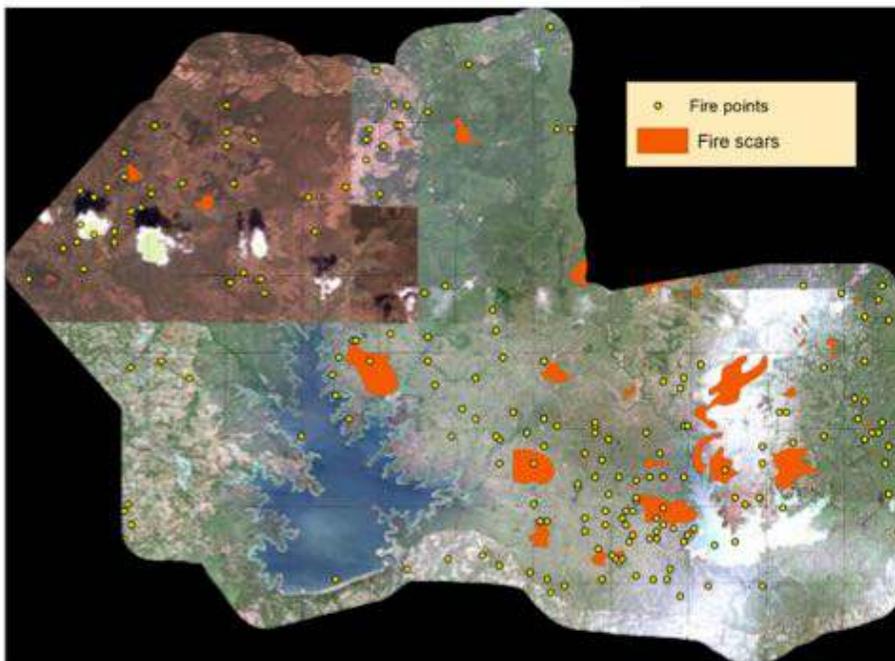


Figure 2. Map of UNP fire points detected by satellite and fire scars digitized from satellite imagery. Based on FIRMS data (NASA/University of Maryland, 2002).



Figure 1. The primary field site, Udawalawe National Park, and Hurulu Reserve, where additional grassland transects are located.

In addition, using aerial photography and previous land use maps spanning the last six decades (Fig. 3), I am documenting the shifting vegetation patterns in UNP and creating a sound scientific and visually compelling argument for the conservation of this prime elephant habitat. This type of study has never been done in Sri Lanka and the impacts potentially could reach millions of people and thousands of elephants by reducing human elephant conflict, and thereby conserving elephants, a vital cultural and religious symbol and main attractant for ecotourism.

Udawalawe - 2010

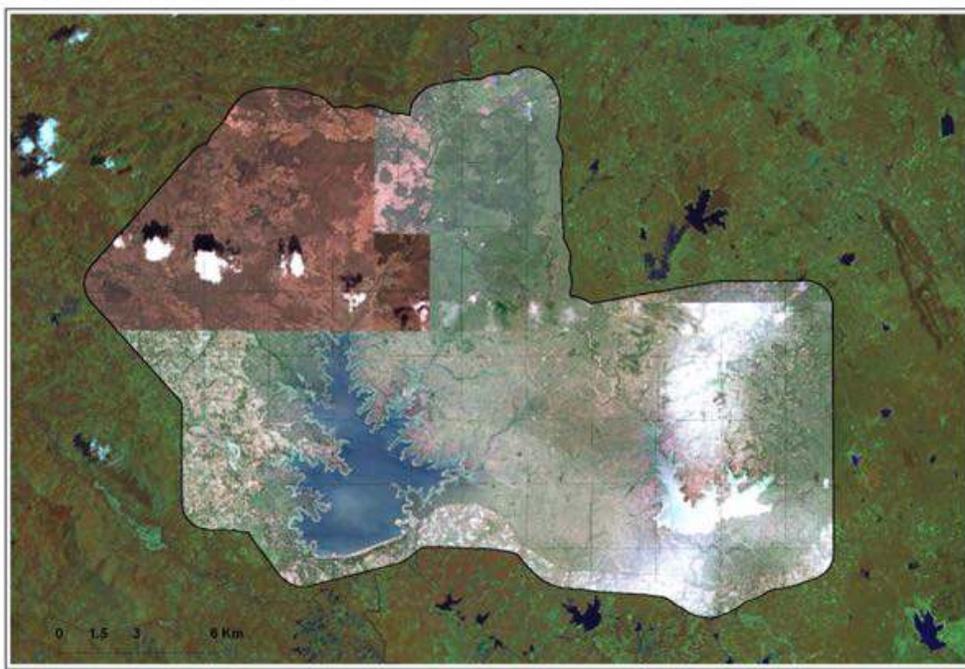


Figure 4. High resolution (1-5m) satellite imagery for UNP.

During my 2011 field season, I established 23 one kilometer dung transects at my primary field site, UNP, which will be used to determine the habitats most often used by elephants. In addition, I established 238 permanent vegetation plots between UNP and HR to assess the vegetative structure of the preferred elephant habitats. I will also use these plots to ground truth the habitat map I am creating from the most current satellite imagery available (Fig. 4). All of these transects and vegetation plots will be resurveyed in the summer of 2012, with final habitat management recommendations for UNP and HR submitted in the summer of 2013.

My first week in Sri Lanka, I found myself hiding in a bedroom with a macaque running loose through the halls of the house. I am now starting my third field season, but I still watch out for the monkeys. My research is constantly challenging me as a scientist and as a human being. That is why I am always inspired by science and dedicated to continuing in this field. I am incredibly grateful for support from the Spatial Ecology and Telemetry Working Group which helped me to share my research at The Wildlife Society annual conference.

Acknowledgements

I'd like to thank my advisor Dr. David Tonkyn of Clemson University, Dr. Peter Leimgruber and Alex Biggs of the Smithsonian Conservation Biology Institute, and Dr. Pruthu Fernando and Dr. Jennifer Pastorini of the Centre for Conservation and Research. Also, thank you to the USFWS Asian Elephant Conservation Fund for their financial support of this project.

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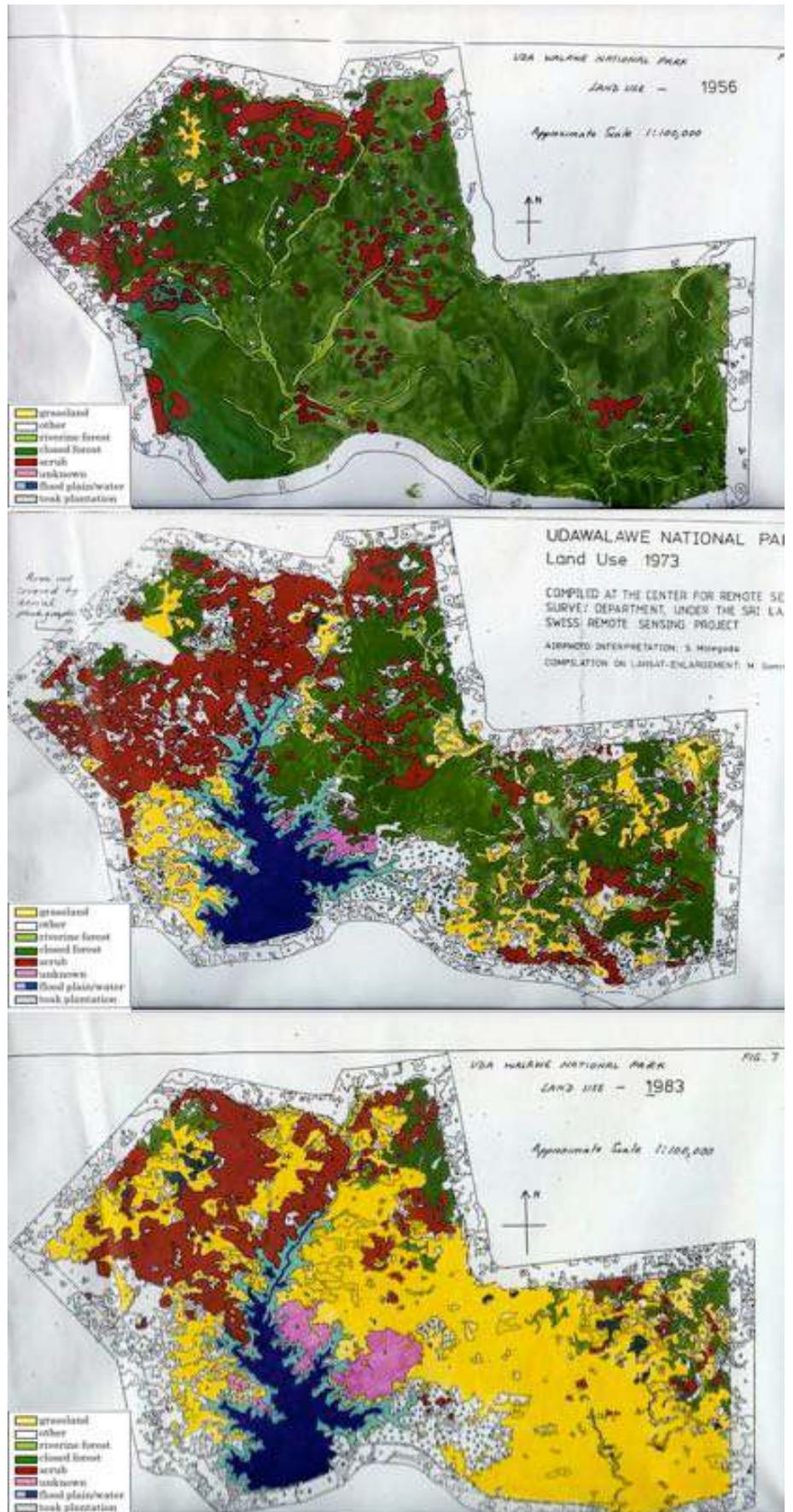


Figure 3. Land cover change in UNP with maps from 1956, 1973, and 1984 (Molegoda, 1984).

Preferred habitat and spatial overlap of red wolves, coyotes, and red wolf/coyote hybrids on the Albemarle Peninsula, NC

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Loss of contiguous tracts of forest considered ideal for wolf (*Canis lupus* and *rufus*) populations and the increase in agricultural lands throughout the 1900s has led to decreases in wolf populations and increases in coyote (*Canis latrans*) populations (Lehman et al. 1991, Ballard et al. 2003, Bekoff and Gese 2003, Thiel 2010). This shift has increased contact between the two species, and for the endangered red wolf (*Canis rufus*) has led to hybridization events (USFWS 1989, Kelly et al. 1999, USFWS 2007).

In order to provide decision-support material for red wolf conservation and establish a baseline for red wolf preferred habitat, we evaluated habitat selection by red wolves, coyotes and hybrids on the Albemarle Peninsula, NC from 1999-2008 using the species distribution modeling method MaxEnt and statistical analyses based on more than 6,000 VHF radio telemetry locations. Predictor variables used to measure habitat selection included five categories of land use/land cover type, canid species density, primary and secondary road density, and human population density. Our objectives were to measure habitat preferences of each group, identify where red wolf and coyote suitable habitat overlap occurred, and characterize the predictor variables that supported overlap between these species. We also identified overlap between red wolves and hybrids in order to determine if the hybrids select habitat similar to red wolves, coyotes, or neither.

Overall, habitat suitability model accuracies were acceptable (Area Under Curve ranged from 0.71 – 0.84) and showed a similar total area predicted suitable for all red wolves and all hybrids, and very little area predicted suitable for coyotes. In general, high suitability areas corresponded with agricultural areas and poor suitability areas corresponded with the urban areas and wetland areas surrounding rivers and the coast (Figs. 1-3).

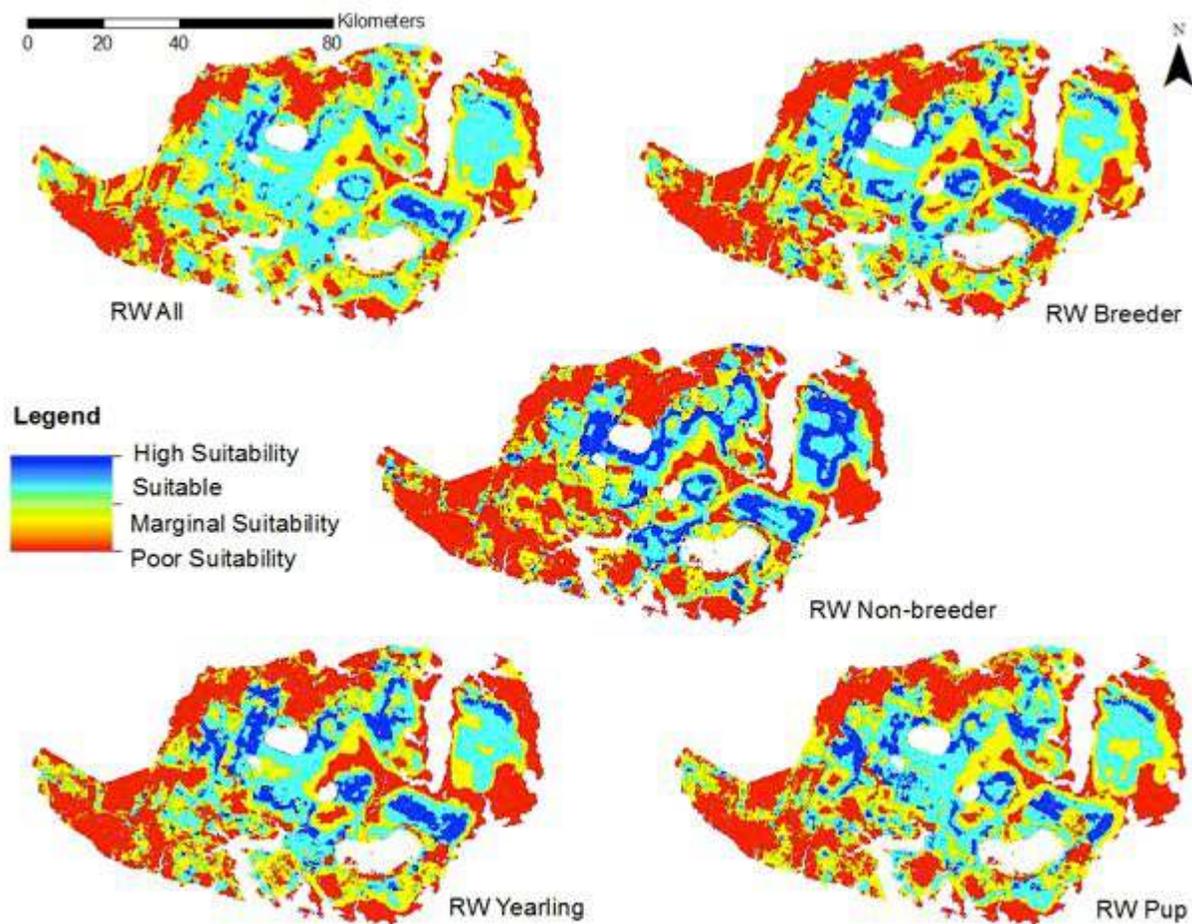


Figure 1. MaxEnt habitat suitability for each red wolf (RW) group on the Albemarle Peninsula, NC in 2008, expressed as categories of suitability.

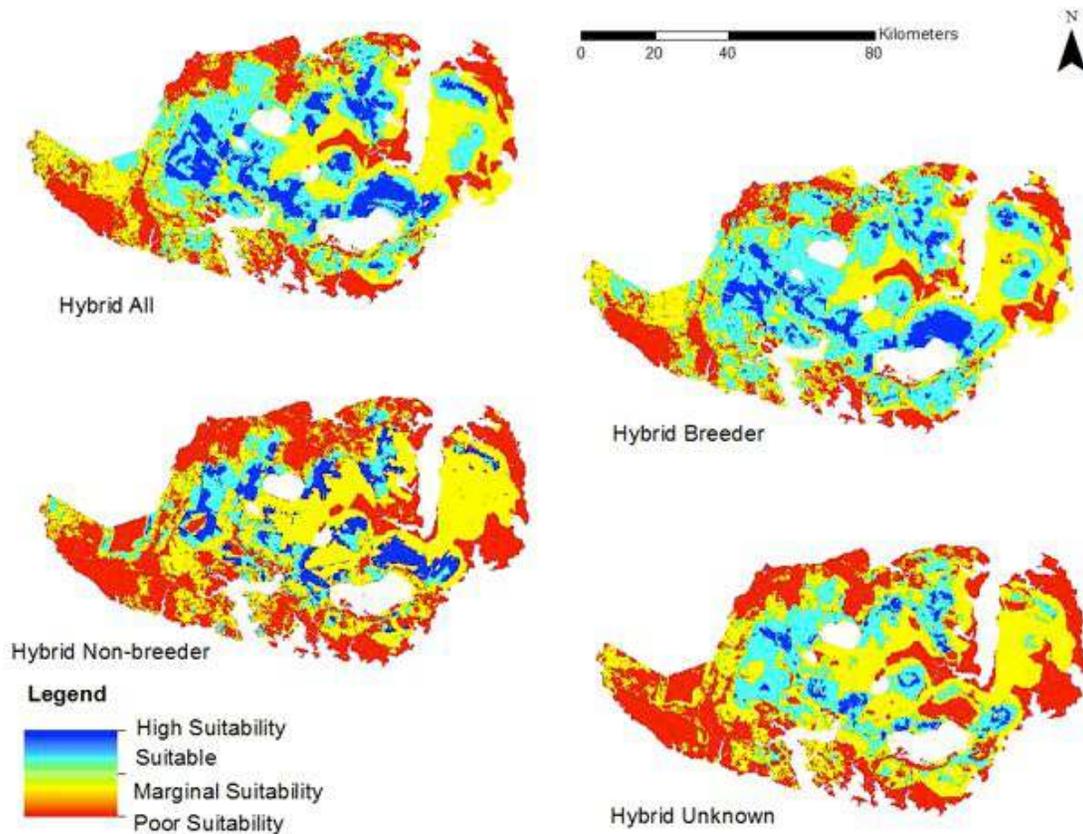


Figure 2. MaxEnt habitat suitability for each hybrid group on the Albemarle Peninsula, NC in 2008, expressed as categories of suitability.

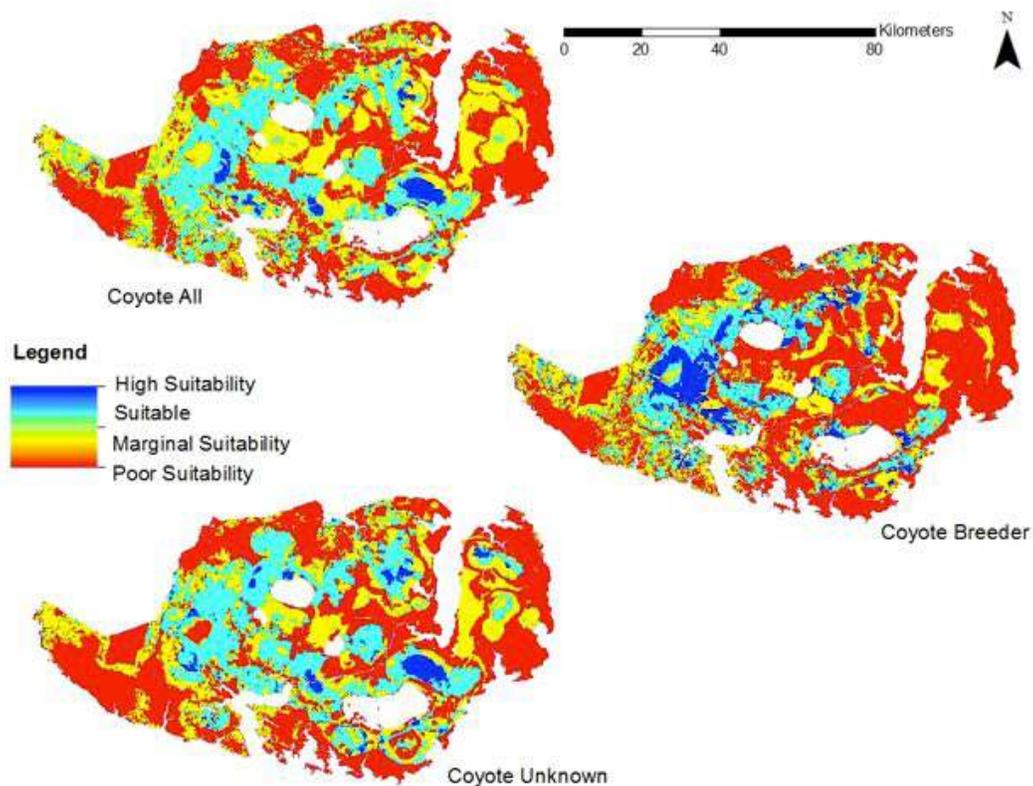


Figure 3. MaxEnt habitat suitability for each coyote group on the Albemarle Peninsula, NC in 2008, expressed as categories of suitability.

The results also indicated that there was similarity in preferred resource types between these three groups based on land use/land cover type and secondary road density, but a clear separation between red wolves and the other groups based on human population density. Red wolves preferred significantly lower human population densities (average 0.47 people/km²) than hybrids or coyotes. Hybrids were tolerant of the highest primary road densities (average 0.137 km/km²) of all groups, while coyotes were tolerant of the highest secondary road densities (average 1.09 km/km²) and human population density of the three groups (average 3.13 people/km²). The suitable models revealed a preference for wetlands for most red wolf groups, while the highly suitable models suggested all groups except red wolf non-breeders preferred agricultural lands. There was 33% of overlap between red wolf and coyote suitable habitat, and the majority of overlap was composed of agriculture. There was 45% of overlap between red wolf and hybrid suitable habitat, and the majority of this overlap also occurred in agriculture and in the western part of the study area.

Our results suggest areas of high human population density may be the best indicators for targeting coyotes for management, and areas of agriculture with lower road and human population density are where the threat of hybridization between red wolves and coyotes may be greatest. Also, we characterized the habitat preferences of hybrids and determined they are tolerant of higher levels of human disturbance than red wolves, as indicated by road and human population density, and are selecting habitat more similar to coyotes in this study area.

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Spatial Ecology & Telemetry Working Group

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Upcoming Events

- * 2012 Wildlife Society Annual Conference, Portland, Oregon - October 13 -18, 2012. <http://wildlifesociety.org/>
- * Monday, October 7, 2013 at 12:30pm
- * 2012 Society for Conservation GIS Annual Conference, July 19-22, Asilomar Conference Grounds, Monterey, CA <http://www.scgis.org/>
- * Ecological Society of America annual meeting, Portland, Oregon, August 5 - 10 2012, <http://www.esa.org/portland/>
- * SCB 26th International Congress for Conservation Biology, Baltimore Convention Center, Baltimore, MD, USA, July 21-25, 2013. <http://www.conbio.org/Activities/Meetings/2013/?CFID=28297613&CFTOKEN=32308370>
- * The Society for Marine Mammalogy, 20th Biennial Conference on the Biology of Marine Mammals, Dunedin, New Zealand, 9-13 December 2013. http://www.marinemammalscience.org/index.php?option=com_content&view=article&id=549&Itemid=65
- * ASPRS 2013 Annual Conference, Baltimore, Maryland, March 24-28. <http://www.asprs.org/ASPRS-Conferences/blog.html>
- * Assoc. of American Geographers, Annual Meeting, Los Angeles, California, April 9 to April 13, 2013, http://www.aag.org/cs/annualmeeting/about_the_meeting
- * GIS-Pro: URISA's 50th Annual Conference for GIS Professionals, September 30 - October 4, 2012, Portland Hilton - Portland, Oregon <http://>