Analyzing GPS Collar Data in ArcGIS 9.1

TWS 2006, Anchorage, AK

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PREFACE:
This worksheet goes through 'how-to' work with GPS collar data in 9.1, but similar methods would be used for other types of location data. We used data from the Starkey Project (details below) in the workshop because it is freely available. We used subsets of the data of various sizes so that processes would run quickly. Be aware that processes may take much longer when working with your own datasets.

Sample Data:

The Starkey Project: http://www.fs.fed.us/pnw/starkey/index.shtml

...is a joint wildlife research project conducted by the Oregon Department of Fish and Wildlife and the USDA Forest Service at the Starkey Experimental Forest and Range, 28 miles southwest of La Grande, Oregon. The project is designed to measure the population response of deer and elk to the intensively managed forests and rangelands of the future. Research began in 1989 and continues for 10 years.

The Starkey Project involves four major studies that document deer, elk and cattle response to intensively managed National Forests. Research animal numbers within the Starkey enclosure include 550 cow-calf pairs, 450 elk and 250 deer.

In the heart of the Blue Mountains of N.E. Oregon, the project takes place at the USDA Forest Service Starkey Experimental Forest and Range on the Wallowa-Whitman National Forest. Access to the Starkey enclosure is 28 miles southwest of La Grande on Highway 244.

NEW TECHNOLOGIES IN USE

An automated Loran-C tracking system generates an animal location every 15 seconds with an accuracy to within 50 meters. Hardware, consists of a base station tower about 200 feet high, two base station computers linked to the

Loran-C system, seven relay towers each about 150 feet high, and radio collars for 180 animals. During the 10 year study, more than four million locations will be generated-over 100 times the capability of conventional tracking systems. The cost per location is less than $ 1, compared to about $75 per location for previous systems.

WHAT ARE THE SYSTEM COMPONENTS?

The automated animal tracking system begins and ends with a computer, and consists of five towers that average 150 feet in height, two base station computer systems linked to Loran-C hardware. and 180 collared animals. The collars contain Loran-C receivers, VHF transmitters, pagers, and batteries with an 16-month life. While these batteries can power the units for 2 full May through mid-December field seasons, they are changed whenever possible to insure adequate coverage. The electronics are connected to a rubberized strip and fitted into PVC pipe. The pipe is heated and molded around one of several forms, depending on the size and species of animal the collar will be used for. Each collar weighs less than three pounds, and is weather and shock resistant.

HOW DOES THE SYSTEM WORK?

A base station computer sends out a location request to a different collar every 20 seconds. Once a collar receives the computer's signal, a pager inside the collar turns on a transmitter and receiver. During the next 10 seconds, the receiver collects Loran-C signals from six out-of-state Loran towers located in Havre, Montana; Williams Lake, British Columbia; George, Washington; Fallon, Nevada; Searchlight, Nevada; and Middleton, California. The transmitter inside the animal's collar then sends the signals to one of Starkey's field station towers. The tower, in turn, retransmits the signals over a microwave link to the base station's Loran-C hardware. Positioning software translates the Loran signals into Northing and Easting coordinates, and then computes locations using differential statistics.

The locations are stored on a hard drive in the computer and later archived to tape. They can also be displayed in real-time on an interactive computerized map in relation to roads, and to forage and other habitat features.

The telemetry system at Starkey can compute one location every 20 seconds, day and night, and is accurate to within 50 meters. By the end of the 10 year study, the automated tracking system will have generated more than four million locations--over 100 times more than are capable using conventional tracking methods. Traditionally, researchers use headsets and antennae to judge the signal strength and bearing of collared animals, often spending hours to determine a single location.

CAN THE SYSTEM PROVIDE ADDITIONAL INFORMATION?

Time and air temperature readings are also provided with each animal location. In addition, the system at Starkey is capable of transmitting pulse rates from animals equipped with special heart monitors.

Lab Objectives:

- Learn to use customized tools in ArcGIS
- Learn to bring in point data from a database
- Learn to create minimum convex polygons and kernel home ranges
- Learn how to obtain random points in a GIS for 3 different domains of availability (Point methods of analysis).
- Convert points to movement paths and calculate various movement parameters.
- Learn to assign habitat variables from other GIS layers to your points, lines, and polygons.
- Create a map of the relative use of a management area (RSF or RUF).

PART I: SETTING UP THE SOFTWARE ENVIRONMENT

Although the software environment has already been prepared for you, it is described here so that you may replicate this environment on your own computer.

Software:

- ESRI's ArcMap (see http://www.esri.com), including the optional "Spatial Analyst" extension
- "Hawth's Analysis Tools for ArcGIS", which is a free extension that can be downloaded from this website: http://www.spatialecology.com/htools
- "Home Range Tools for ArcGIS", which is a free extension that can be downloaded from: http://blue.lakeheadu.ca/hre
- Although not used in this class, we also recommend the use of "R", which is a language and environment for statistical computing and graphics. It is open source and can be downloaded from: : http://www.r-project.org (see Download > CRAN). This website also has a collection of user manuals and language references pitched at every level of user (see Documentation > Manuals). Of particular note is the "contributed documentation" link on the Manuals page, which contains links to over 18 contributed manuals.

GETTING STARTED: LOOKING AT THE SPATIAL DATA

To open ArcMap, go to Start > Programs > ArcGIS > ArcMap.

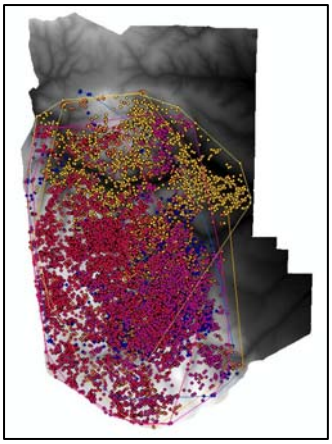
On the first screen that appears, select the option for a new empty map.

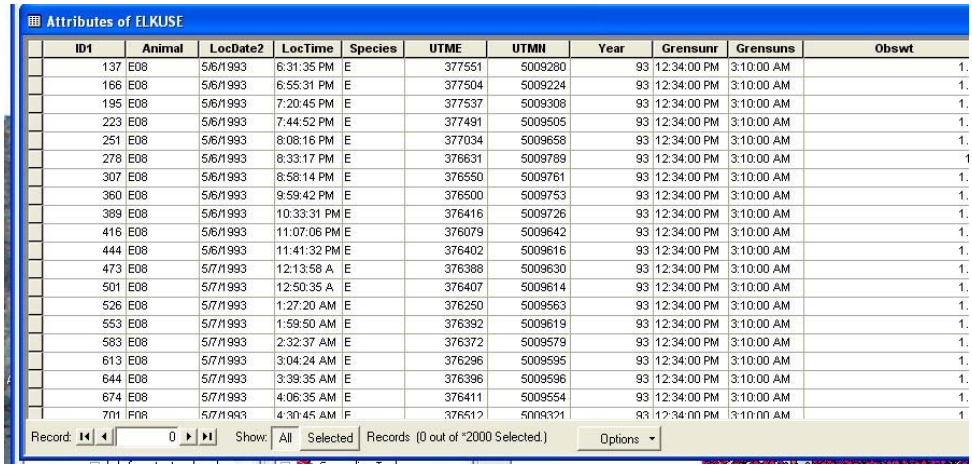
Save the file as: GPSCollarWorkshop.mxd

If you haven't used ArcMap much: The layers that you will add can be switched on and off using the check-mark boxes. Some other tools you may find useful are shown below.

Zoom in
Zoom out
Pan (click and drag map)
Zoom to full extent (extent of all layers)
Identify (report the value of the top visible layer at the location you click)
Measure distance
Pointer (the default tool when you are not using the other tools)

ELK USE DATA





Attributes of ELKUSE

ID1	Animal	LocDate2	LocTime	Species	UTME	UTMN	Year	Grensunr	Grensuns	Obswt
137	E08	5/6/1993	6:31:35 PM	E	377551	5009280	93	12:34:00 PM	3:10:00 AM	1.
166	E08	5/6/1993	6:55:31 PM	E	377504	5009224	93	12:34:00 PM	3:10:00 AM	1.
195	E08	5/6/1993	7:20:45 PM	E	377537	5009308	93	12:34:00 PM	3:10:00 AM	1.
223	E08	5/6/1993	7:44:52 PM	E	377491	5009505	93	12:34:00 PM	3:10:00 AM	1.
251	E08	5/6/1993	8:08:16 PM	E	377034	5009658	93	12:34:00 PM	3:10:00 AM	1.
278	E08	5/6/1993	8:33:17 PM	E	376631	5009789	93	12:34:00 PM	3:10:00 AM	1
307	E08	5/6/1993	8:58:14 PM	E	376550	5009761	93	12:34:00 PM	3:10:00 AM	1.
360	E08	5/6/1993	9:59:42 PM	E	376500	5009753	93	12:34:00 PM	3:10:00 AM	1.
389	E08	5/6/1993	10:33:31 PM	E	376416	5009726	93	12:34:00 PM	3:10:00 AM	1.
416	E08	5/6/1993	11:07:06 PM	E	376079	5009642	93	12:34:00 PM	3:10:00 AM	1.
444	E08	5/6/1993	11:41:32 PM	E	376402	5009616	93	12:34:00 PM	3:10:00 AM	1.
473	E08	5/7/1993	12:13:58 A	E	376388	5009630	93	12:34:00 PM	3:10:00 AM	1.
501	E08	5/7/1993	12:50:35 A	E	376407	5009614	93	12:34:00 PM	3:10:00 AM	1.
526	E08	5/7/1993	1:27:20 AM	E	376250	5009563	93	12:34:00 PM	3:10:00 AM	1.
553	E08	5/7/1993	1:59:50 AM	E	376392	5009619	93	12:34:00 PM	3:10:00 AM	1.
583	E08	5/7/1993	2:32:37 AM	E	376372	5009579	93	12:34:00 PM	3:10:00 AM	1.
613	E08	5/7/1993	3:04:24 AM	E	376296	5009595	93	12:34:00 PM	3:10:00 AM	1.
644	E08	5/7/1993	3:39:35 AM	E	376396	5009596	93	12:34:00 PM	3:10:00 AM	1.
674	E08	5/7/1993	4:06:35 AM	E	376411	5009554	93	12:34:00 PM	3:10:00 AM	1.
701	E08	5/7/1993	4:30:45 AM	E	376512	5009321	93	12:34:00 PM	3:10:00 AM	1

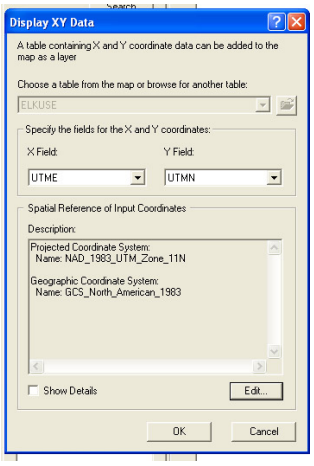
Record: 0 Show: All Selected Records (0 out of *2000 Selected.) Options

Selected 5 elk from the database to use as examples for processing. Number of locations per individual elk ranges from 2881 to 4007.This may be comparable to GPS collar data – notice that it's pretty difficult to say much – there are too many points to see the patterns! Note that even with this limited sample, some of these functions take a long time—we'll use even smaller subsets to demonstrate some processes.

1. Add the data layers: There are data available on 4 GIS layers that we will use to develop typical layers used in habitat analysis. In ArcMap, add the layers to the project, adjust the symbology, and inspect the layers:

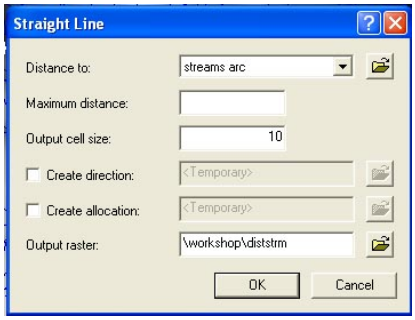
Name	Description	Min	Max	File type
starkey_dem	Elevation (meters)	1120	1501	Raster
roads arc	Roads Coverage			Line
streams arc	Streams Coverage			Line
Veg_ecoclass	Vegetative Ecoclass Field: Veg_type_C gives the dominant covertype			Polygon

2. Bring in the elk locations



- Add the file ELKUSE from LocationData.mdb in the workshop folder. Right click on it and choose Display XY Data. Select UTME as the XField and UTMN as the YField.
- Click on Edit to choose the Projection: Import the projection from starkey_dem in the workshop folder.
- Click OK.

3. Calculate the distance to stream for the entire study area

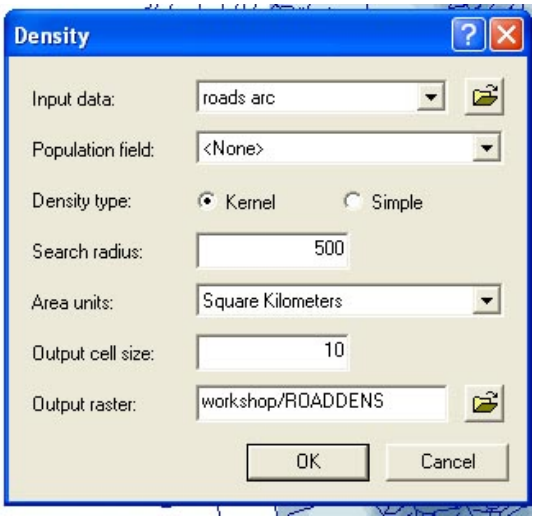


- First select SPATIAL ANALYST/OPTIONS. Set the working directory to the workshop folder. Set starkey_dem as the analysis mask. This will force all grids that you make to have the same extent and cell size as the DEM. Choose starkey_dem under the Extent and Cell Size tabs as well.

- Choose SPATIAL ANALYST/ DISTANCE/STRAIGHT LINE. The settings should match the starkey_dem settings (shown here). Choose streams arc as the layer to create the distance to. Browse to the workshop folder and save the output raster(aka grid) file as DISTSTRM

- *This creates a raster version of distance to stream, which is faster for processing, but it is also possible to calculate distance from individual features to another point or line

4. **Calculate the road density for the entire study area.**
   - Select Spatial Analyst/Density. Select roads arc as the input data. This is one calculation for which you have several options. In this case choose Simple density type (you can read more about kernel vs. simple densities in the help files). You also have to choose a scale – search radius, which refers to the area within which density will be calculated. Choose 500. This refers to meters, which are the units of the data frame. Choose square kilometers as the area units—so that density will be calculated in m/ km^2. Save the output raster to the workshop folder as ROADDENS.



5. **Calculate the slope for the entire study area.**
   - Spatial Analyst/Surface Analyst/ Slope
   - Choose percent and save to the workshop folder as Slope

CREATE MINIMUM CONVEX POLYGONS AND KERNEL HOME RANGES

In this section we will investigate a new tool for ArcGIS, Home Range Tool, created by Art Rodgers and John Kie. The home range calculations within this tool are directly from the published literature. Because different software calculates home ranges slightly differently, always cite the software used to create them. This software is still under development – they are working with Hawthorne Beyer to incorporate batch processing and grid output. Art also noted that the HRT works with ArcGIS 8.x but it will not do the calculations of distance and time (the fields are created but they are blank).

1. **Add the layer Elk06Verysmall for use in this exercise. It contains only part of the locations for one animal, which is how HRT is currently set up.**

2. **Minimum Convex Polygons**

- This version creates percent minimum convex polygon home ranges based on various rules. We will examine 2.

- Add ELKUSEVerySmall

- First select ELKUSEVerySmall in the list of layers on the left.

- Select ELKUSEVerySmall. Select all locations in ELKUSEVerySmall

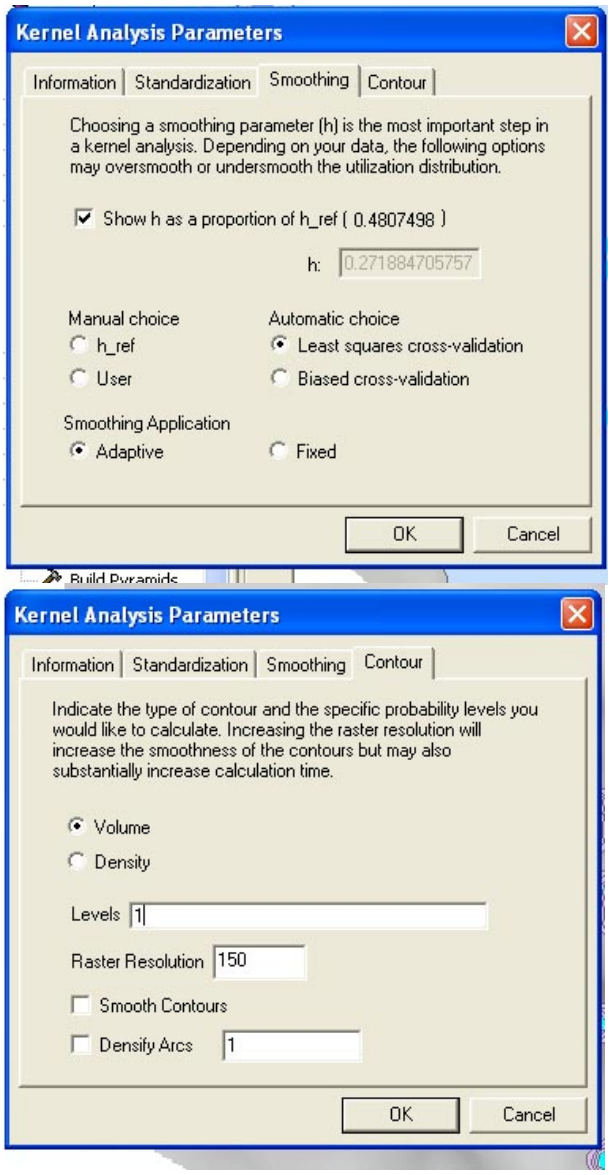
- In HOME RANGE TOOLS click on the MCP button. Choose 90% and then pick Floating Mean. Save as Elk06FloatingMCP. This method calculates the arithmetic mean of all points, and then drops the farthest single point. It then recalculates the mean on remaining points and repeats until the requested percentage of points remain selected.

- In HOME RANGE TOOLS click on the MCP button.

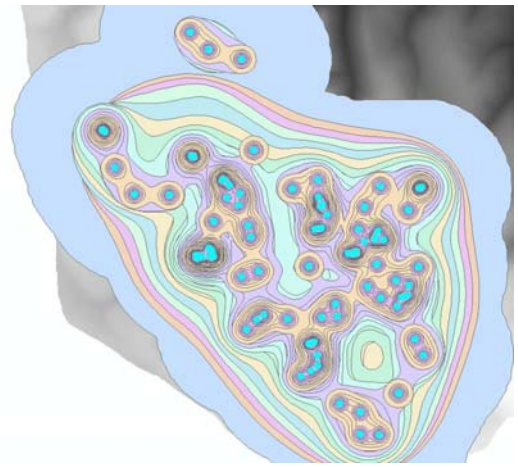
- *Confirm that MCP for: Elk06Verysmall heads the window that opens.* Choose 90% and then pick Area Added. Save as Elk06AreaMCP. This method drops points based on the amount of area they add to the home range polygon. Because this iteratively creates points it can be extremely slow (so prepare to leave it run overnight for larger data sets or different settings).
- Compare the two MCPs that you have created.

3. Kernal Home Ranges

- Choose the Kernal button in HOME RANGE TOOLS.
- This procedure calculates two statistical measures of autocorrelation. Schoener's (1981) and Swihart and Slade(1985) indices are given at the top of the dialog box. High values (>0.6) of Swihart & Slade index indicate significant autocorrelation, and if that is a concern you may wish to delete locations, using the method developed by Swihart and Slade(1985). However, if your data is systematically collected, and your goal is to use the UDs in other analyses where autocorrelation is of interest, you may wish to include all locations.
- Under the smoothing tab, choose Least squares cross-validation (to pick a smoothing parameter) & Fixed (as smoothing application: both recommended by Marzluff for use in UD calculations)
- Under the contour tab, choose Volume, and choose 1 as the percent (for 100%). Use the default



resolution (150) and click OK. Save as Elk06khr in the workshop folder.



- Repeat but choose Adaptive as the smoothing application and leave the default range of percentage kernel home ranges.

- Compare results from the two processes.

- Fixed kernel methods assumes the width of the standard bivariate normal kernel placed at each observation is the same throughout the plane of the UD. If there are outlying regions of low density it is difficult to select a smoothing parameter that will accommodate these outer areas without oversmoothing the core of the distribution. Adaptive kernel allows the width of the kernel to vary such that regions with lower densities are smoothed more than areas of high concentration. This widening of the kernel in outlying regions may unacceptably expand the UD however, so examine the data and check out the latest literature to help choose the appropriate method.

- Volume contouring surrounds regions of equal probability, so that for a 95% volume contour surrounds an area within which an animal spends 95% of its time (i.e. there is a 95% chance of finding the animal within that area.) Volume contours are generally used in home range analyses.

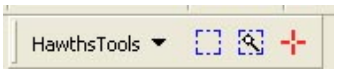
- Probability densities are estimated at the center of each cell in a grid of cells. If the resolution is low (e.g. below 50X50 cells), the angularity of contours derived from the raster may produce inaccurate home range estimates. Memory concerns limit the upper resolution to about (150X150). This problem has not been thoroughly investigated, but consider this issue in your resolution choice.

4. Other Features to Explore

- "Moose On A Leash" is a great exploratory tool to examine how the animal moves through time. * Uses 2 fields 'Date' (YYYYMMDD) and 'TimeOfDay' (HHMMSS), both in number format, so may need to add and calculate these fields.
- Automated import of .dat files from Lotek collars

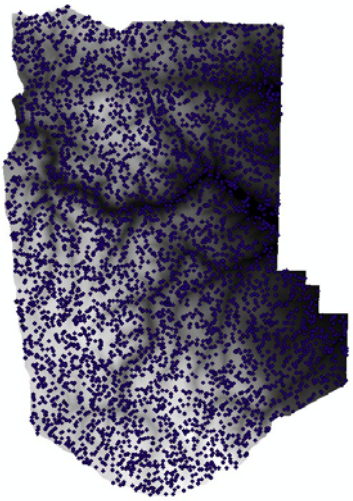
OBTAINING RANDOM POINTS WITHIN DIFFERENT AVAILABILITY DOMAINS

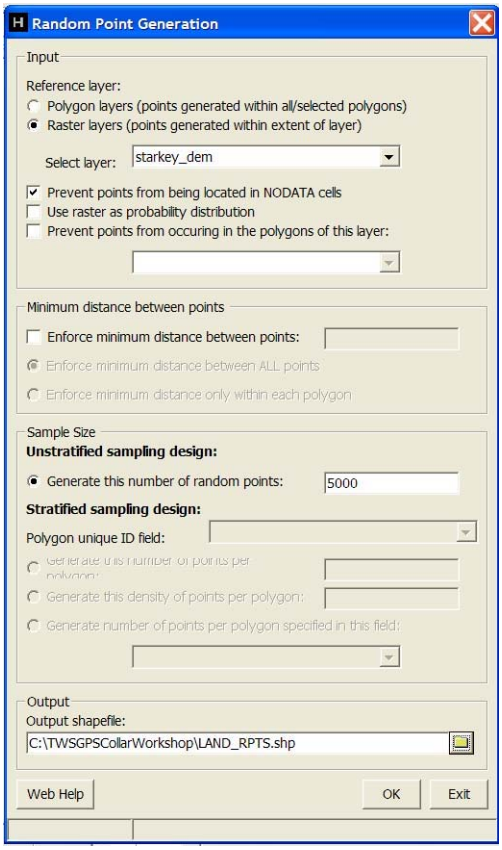
An important decision in developing an RSF is picking the correct domain of availability. In this section random points for 3 different domains are obtained using the GIS. It is extremely important to give careful consideration to your definition of 'availability' – Consider temporal as well as spatial divisions.



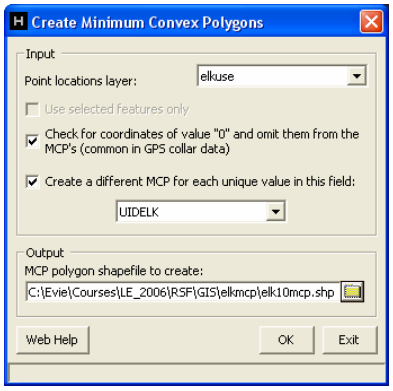
1. Entire landscape scale domain of availability: generate random points within the entire landscape of interest (the DEM).

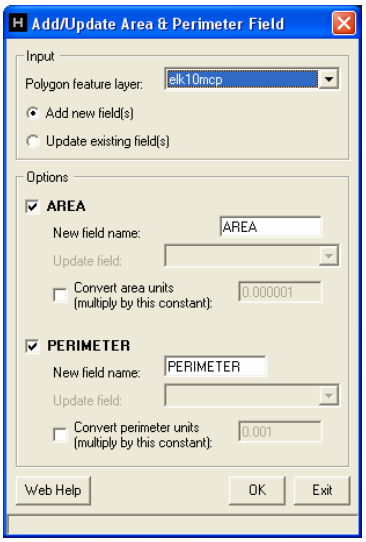
- Select HawthsTools/ SAMPLING TOOLS/GENERATE RANDOM POINTS and toggle on *Raster Layers.*
- Select *starkey_dem.*
- Toggle on *Prevent points from being located in NODATA cells*
- Skip the other options, including prevent points from occuring in the polygons of this layer (which could be used to exclude e.g. lakes or glaciers).
- Toggle on the *Generate this number of random points* and select 5000; select an output file name: LAND_RPTS and location.





2. Home range-scale domain of availability:
Generate random points that occur within the minimum convex polygon (MCP) home range of each elk and match the availability points to each individual animal.





- Create MCP for each elk by selecting HawthsTools/ ANIMAL MOVEMENTS/CREATE MINIMUM CONVEX POLYGON. Select ELKUSE as the point locations layer. Toggle on *Create a different MCP for each unique value in the field: Animal.* Output the file to the workshop folder as ELKMCP.

- Select HawthsTools/TABLE TOOLS to add the area and perimeter length to the MCP polygon. Select the polygon feature as ELKMCP and toggle on the *area* and *perimeter* boxes. Open the attribute table of ELKMCP.

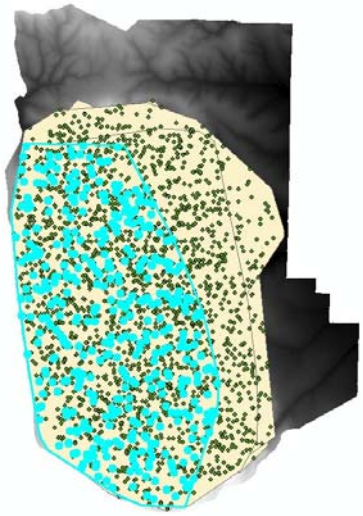
- Generate random points within each home range by opening Hawths tools and selecting SAMPLING TOOLS/GENERATE RANDOM POINTS.

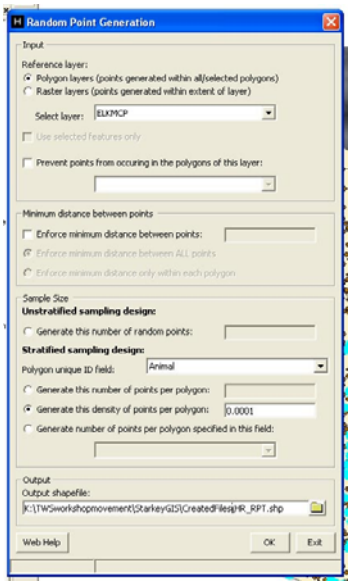
- Toggle on polygon layer for the pts to be generated in and select ELKMCP

- To generate the same sampling intensity, toggle on GENERATE DENSITY…and input **0.00001** pts/m^2 or 1pt/100m^2.

- Select *Animal* for the unique ID field.

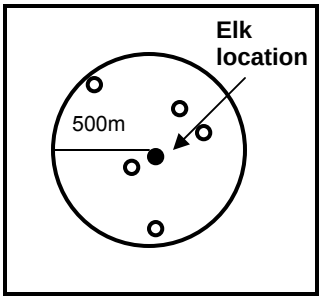
- Save as HR_RPTS in the workshop folder.



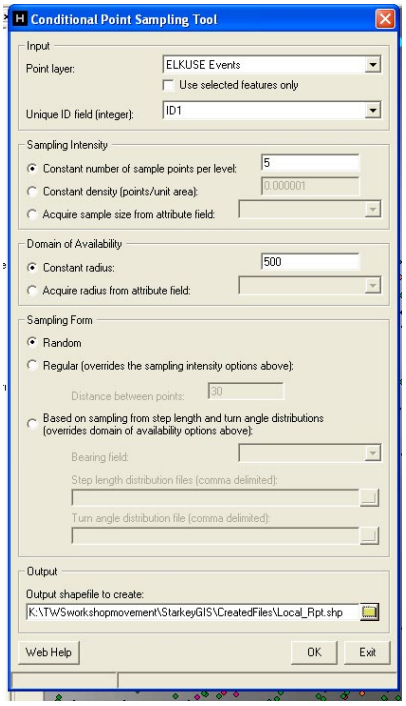


3. Changing availabilities with elk location: conditional sampling at small scales

Availability often can be limited by how far the animal can move in the designated time step. In this approach, each elk location is matched with a set of points located randomly within the designated radius (see figure).



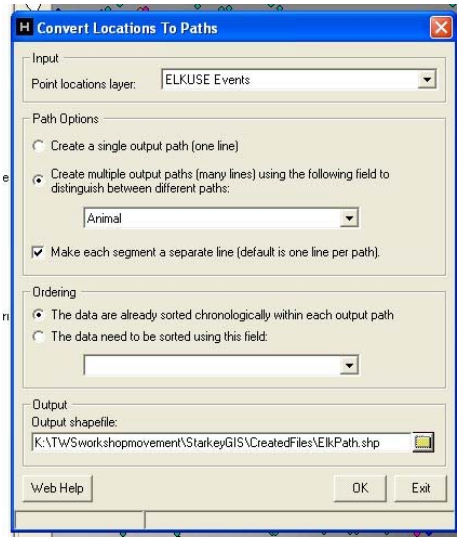
- Select SAMPLING TOOL/CONDITIONAL POINT SAMPLING TOOL
- Select ELKUSEVerysmall as the point layer and use ID1 as the unique id field.
- Input 5 random pts per elk location in constant points per level.
- Use a constant radius of **500 m**. For many other examples you could use the mean, median, or maximum distance (must be calculated as a field) moved by the animal in the time step. The choice here should be based on the biology of the animal and requires careful consideration.
- Select random for the form of sampling.
- Save as LOCAL_RPT in the workshop folder.
- Inspect the results by first opening the ELKUSEsmall attribute table and selecting the record where ID1= 137. Close the table and in properties for ELKUSEsmall, change the Selection/Color to bright yellow so you can see it easily.
- Next open the LOCAL_RPT attribute table and select all records with ID1 = 137. Close that table and then right Click on the Local_Rpt layer and choose Selection/ zoom to selection.



4. Step Selection: The last option in the menu allows you to select a random location based on the observed distributions of step lengths and turn angles from the elk locations.

- Need a field in the file with bearing and a separate .csv file with a distribution of turning angles and lengths. CHALLENGE if you are an advanced user (of GIS) & are way ahead of everybody else…. Figure this out! Check out the file CHALLENGE on the CD for more info. You can wait until after the next section though if you like.

CONVERT POINTS TO MOVEMENT PATHS AND CALCULATE VARIOUS MOVEMENT PARAMETERS.



- In Hawth's tools, select the ANIMALMOVEMENTS/CONVERT LOCATIONS TO PATHS TOOL. Select the ELKUSEsmall.shp file and choose CREATE MULTIPLE OUTPUT PATHS using the ANIMAL field to distinguish between different paths. Toggle on Make each segment a separate line. Save the shapefile as ELKPATH in the workshop folder.

- In Hawth's tools, select TableTools/Add Length Field to Table

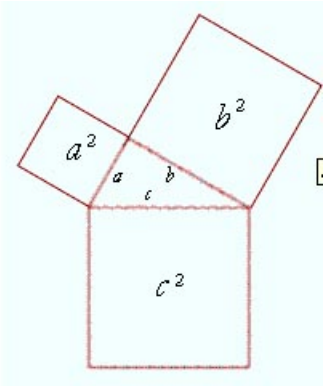
- Movement parameters can be calculated outside of ArcGIS if desired. It's ONLY trig. ☺

- Close Arc and open the Access database Location.mdb. Create a new query by clicking Queries/New. Save as Calc Movement1

- Add the table ELKUSEsmall to the query view. Add the following fields:

    - Animal,
    - DateTimeSerial
    - UTME
    - UTMN
    - In a blank field column add: OrderIDPrev: [OrderID]+1 This makes it possible to look at the record before a location with the current location through a join (next step). Save as CalcMovement1 and close.

CALCULATING DISTANCE, TIME BETWEEN LOCATIONS, AND SPEED (m/hr)



- Trigonometry Reminder : Pythagorean theorem $a^2 + b^2 = c^2$
- Given 2 locations in UTMS or another coordinate systems that is distance consistent (VERY IMPORTANT: see ArcGIS help/Projections for more info), we can get the length of a side by calculating Sqr((UTME1-UTME2)^2 + (UTMN1 –UTMN2)^2)

- VERY IMPORTANT: Time calculation varies greatly between software. I like to convert it into serial number format to do the calculations and then convert it back to hours. Remember it's not base 10! Some programs do this correctly automatically, but will still output the result as a date format. In Access I created a new Number field: DateTimeSerial and then used an update query to add LocDate & LocTime.
- Create a new query.
- Add Table: ELKUSEsmall and Query: CalcMovement1. Create joins between Order ID and OrderIDPrev and between Animal and Animal (this prevents calculation of distance between the last location of Animal 1 and the first location of Animal 2. If you had breaks in your data collection schedule – e.g. between years, you could also add those fields (e.g. Year) to CalcMovement1 and join them together here to prevent spurious calculations.

- Add the following fields: *In the first four fields, we are only renaming the field.

    - DateTimePrev: DateTimeSerial

    - UTMEPrev: UTME

    - UTMNPrev: UTMN

    - AnimalPrev: Animal

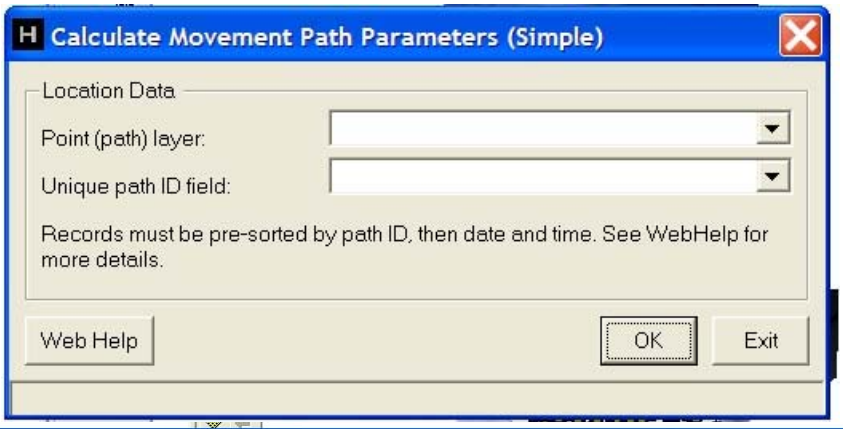
    - DistPrev: Sqr((ELKUSEsmall!UTME-CalcMovement1!UTME)^2+(ELKUSEsmall!UTMN-CalcMovement1!UTMN)^2)

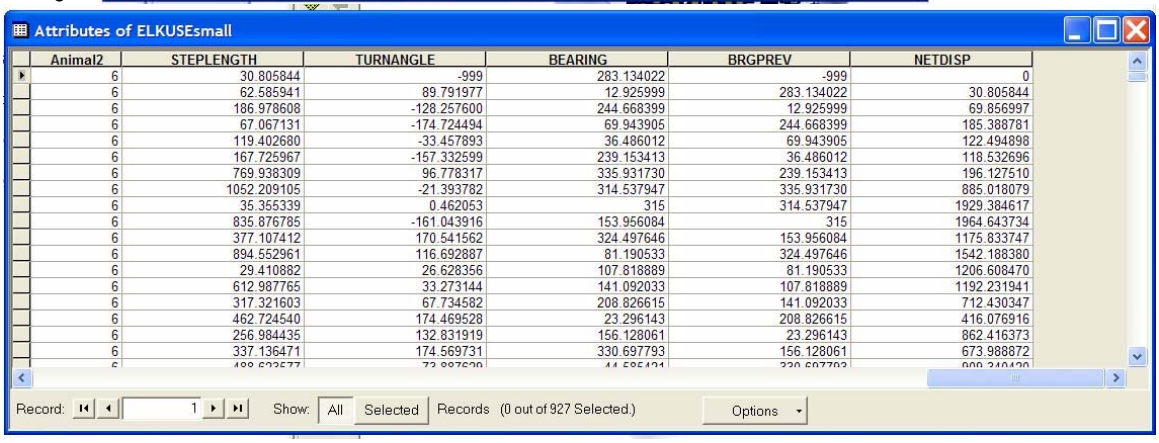
    - HourInt: Hour(ELKUSEsmall!DateTimeSerial-CalcMovement1!DateTimeSerial)+Minute(ELKUSEsmall!DateTime Serial-CalcMovement1!DateTimeSerial)/60

    - SpeedMHr: Sqr((ELKUSEsmall!UTME-CalcMovement1!UTME)^2+(ELKUSEsmall!UTMN-CalcMovement1!UTMN)^2)/(Hour(ELKUSEsmall!DateTimeSerial-CalcMovement1!DateTimeSerial)+Minute(ELKUSEsmall!DateTime Serial-CalcMovement1!DateTimeSerial)/60)

- Change the Query to a MakeTable query creating a table called Movements and run it (Exclamation point button) Save this as CalcMovement2
- Close Access and Open ArcMap Add the table Movements from Locations.mdb and join it to ELKUSEsmall based on OrderID from both tables.

CREATE MOVEMENT PARAMETERS (The Easy way)

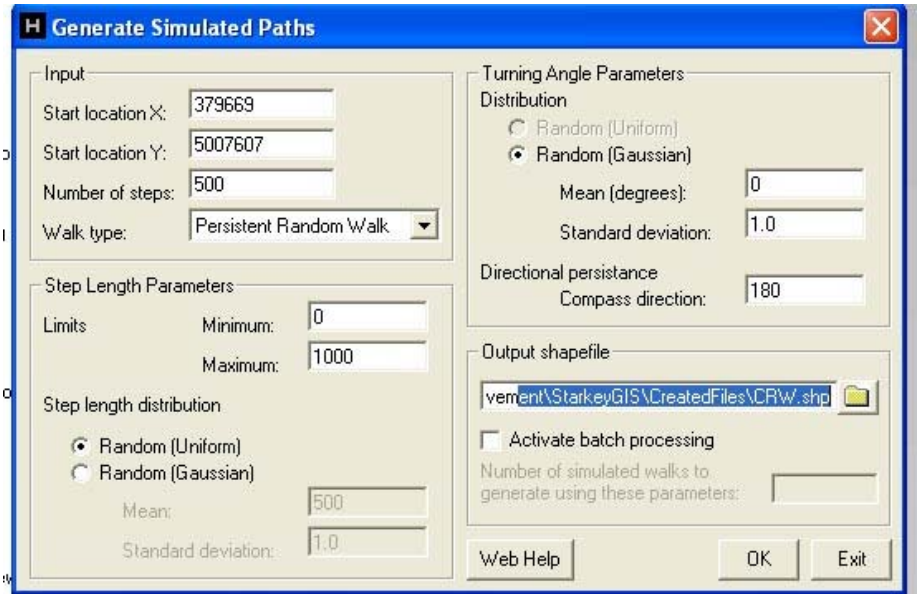
- Now that you've struggled just a little bit, here's an easier way to calculate some of those movement parameters plus a few others.
- In Hawth's tools, select AnimalMovements/ Calculate Animal Movements
- One trick to this is that there has to be a an animal ID field (Unique path ID field & it has to be long integer format.
- 

- 

Animal2	STEPLENGTH	TURNANGLE	BEARING	BRGPREV	NETDISP
6	30.805844	-999	283.134022	-999	0
6	62.585941	89.791977	12.925999	283.134022	30.805844
6	186.978608	-128.257600	244.668399	12.925999	69.856997
6	67.067131	-174.724494	69.943905	244.668399	185.388781
6	119.402680	-33.457893	36.486012	69.943905	122.494898
6	167.725967	-157.332599	239.153413	36.486012	118.532696
6	769.938309	96.778317	335.931730	239.153413	196.127510
6	1052.209105	-21.393782	314.537947	335.931730	885.018079
6	35.355339	0.462053	315	314.537947	1929.384617
6	835.876785	-161.043916	153.956084	315	1964.643734
6	377.107412	170.541562	324.497646	153.956084	1175.833747
6	894.552961	116.692887	81.190533	324.497646	1542.188380
6	29.410882	26.628356	107.818889	81.190533	1206.608470
6	612.987765	33.273144	141.092033	107.818889	1192.231941
6	317.321603	67.734582	208.826615	141.092033	712.430347
6	462.724540	174.469528	23.296143	208.826615	416.076916
6	256.984435	132.831919	156.128061	23.296143	862.416373
6	337.136471	174.569731	330.697793	156.128061	673.988872

CREATE CORRELATED RANDOM WALKS

- This is a tool to help you examine CRW. Choose HawthsTools/Animal Movements/ CRW Simulation Tools/ Simulator I. And set it up as shown below, but save it in the workshop folder as CRWSouth.



- Open the attribute table, Right click on length, and choose statistics.
- Now repeat the steps, but choose a Gaussian Step Length.
- Compare the differences.
- Now make 2 additional walks.
  - Pure Random Walk with a Gaussian distribution (default values) for step length parameters.
  - Correlated Random Walk with Gaussian distributions for step length and turning angle.
- Compare the differences—looking at all of these, what are some of the problems with this in terms of using walks created these ways as your simulated walks?

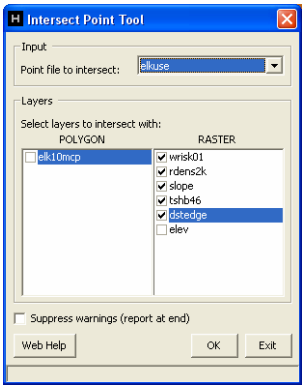
PREPARING FOR A RUF ANALYSIS

- First you need to calculate a UD in a raster format so that there is a continuous estimate of use across the individual/area of interest. The grid should match with your other raster layers if possible.
- Several options:
    - It will be possible to do this within the Home Range tool in the future—with all the various options.
    - Can do within Hawth's tools/Kernel Tool/Fixed Kernel Estimator
    - Can do with Spatial Analyst/Density. See articles about home range estimation before deciding to go this route.
- Use Hawth's tools/Kernel tool/Fixed Kernel estimator for this example. Save the grid in a separate folder within the workshop folder. It will be called 'kde'
- Next get the center of each grid as a point.
    - First need to have an integer grid with the same extent and cell size. In SpatialAnalyst/Options Choose kde as the mask,extent, and cell size. Then choose Spatial Analyst/Raster Calculator and put in the formula kde>0. The resulting calculation will have values of either 0, 1 or nodata—an integer grid, and will have the same cell centers as the UD.
    - Choose Spatial Analyst/Convert Raster to Features. Choose Calculation as the Input raster, Value as the Field, Points as the output geometry type and save as UDcenters.
- Choose HawthsTools/TableTools/Add XY to Table and add the coordinates to the UDcenters (this is for calculating distance between points later—when you get to deal with the spatial autocorrelation.
- Get the UD and habitat values for UDcenters as described in the next section.

ASSIGN HABITAT VARIABLES FROM OTHER GIS LAYERS TO YOUR POINTS, LINES, AND POLYGONS.

POINTS

1. **Intersect elk locations with GIS data layers** to obtain the values of each of the data layers at each of the locations use HAWTHTOOLs to intersect the point location with each of the data layers.*Note that it may be simpler to join all locations (used and available) first—depending on the statistics software you will be using and whether you have multiple scales of analysis.

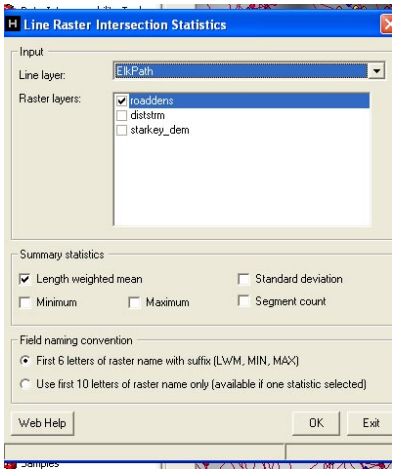


- First clear any selected points in ELKUSEsmall.
- Select ANALYSIS TOOLS/INTERSECT POINT TOOL and in the input box select ELKUSE as the point intersect file and select each of the data layers of interest.
- If you added multiple layers with the same field names (e.g. Value), you will be prompted to rename them--- do so in a logical manner, e.g. Diststrm
- When completed, inspect the results of the intersection by right clicking on ELKUSE file and opening the attribute table. Values of each variable have been added to this file.
- Note that the field from the DEM is called 'Starkey' Rename this to be more useful by clicking on the Options button in the attribute table/AddField. Name the field ELEV of type Long Integer (since DEMs are only accurate to ~10m, we can certainly remove the decimal—also keeps the file size smaller). To keep the file clean, right click on Starkey and Delete Field.
- Output this file as **.dbf* file for statistical analyses by opening the attribute table and selecting OPTIONS/EXPORT and saving it to the workspace.
- Repeat the above process for LAND_RPTS, HR_RPTS, and Local_RPTS as you did for the elk use locations.

LINES

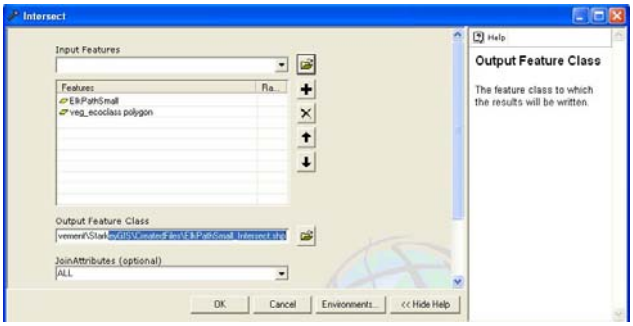
2. Intersect ELKPATH with GIS data layers to obtain summaries of habitat values along the line. This process would be used to prepare data for a step selection function analysis or to quantify the range of one habitat variable (e.g. elevation or canopy cover) along a linear feature such as a road or stream.

Rasters:



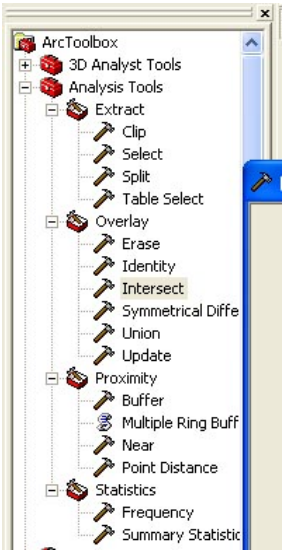
- Choose ANALYSIS TOOLS/LINE RASTER INTERSECTION STATISTICS
- Select the roaddens raster and choose one of the summary variables.
- Will add a column to the line file with the calculated values.
- Currently gives an 'overflow' error message if the line length =0, Choose ok, a value of -999 will be assigned to that 'line'

Polygons:



- This process involves 2 steps. First an intersection to combine all the polygon information and then database management to get your data into a format you can join with your original table file.
- One of the tricky pieces here is to make sure first that all of your lines have unique identifiers so that you can join the attribute table from the intersection back to the path layer if you have both raster and polygon data to join. Luckily, ArcGIS automatically includes the FID from the layers that are being joined. Be aware however that if you delete one line (not sure why you would, but let's just say you need to for some reason), the FIDs in the original table will change. You can prepare against this by creating your own unique id. Right click on the ID field (currently all =0) and choose Calculate. By clicking on the field name first, enter the formula [FID] +1, and hit OK
- Open the ElkPathSmall_Intersect attribute table. Notice that although ElkPathSmall only had 16 lines, there are 33 records in the new layer. This is because some lines intersected more than one polygon.

- If you were after something like: percent of line in each Veg_type_N, you first need to transpose the data. In the Data Management Tools/Table/Pivot Table Select ElkPathSmall_Intersect as the input table, Id as input fields, VEG_TYPE_N as the pivot field, and SHAPE_LENG as the Value Field. Save in the workshop folder as ElkPathPivot
- Finally, join the newly created pivot table back to your Lines based on ID.

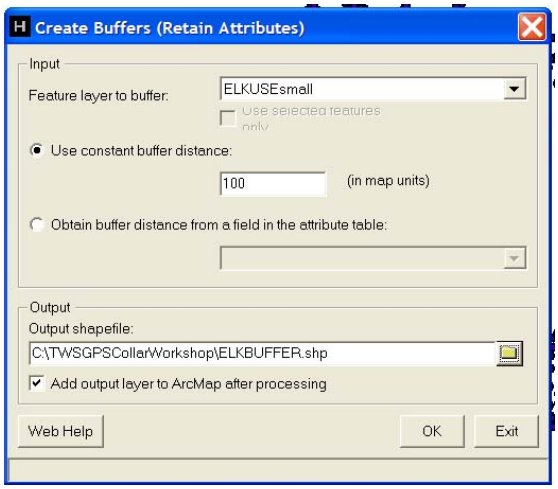


POLYGONS

3. Intersect ELKBUFFER with GIS data layers to obtain summaries of habitat values within another polygon layer. This process would be used to prepare data for a use/availability design where both sets of locations were modeled as areas (perhaps to incorporate error) or to characterize habitat within a home range.

Polygons

- First create ELKBUFFER using HawthsTools/VectorTools/ Buffer Features. Use ELKUSEsmall as the input point file and buffer by 100m (a very rough approximation of GPS collar error post SA) This tool is different from the standard ArcGIS buffer tool in that it retains your attributes—very handy if you decide to subset your analysis by time of day for example.
- Use the Intersect tool as described above in Lines/Polygons (choose ELKBUFFER and then veg_ecoclass)

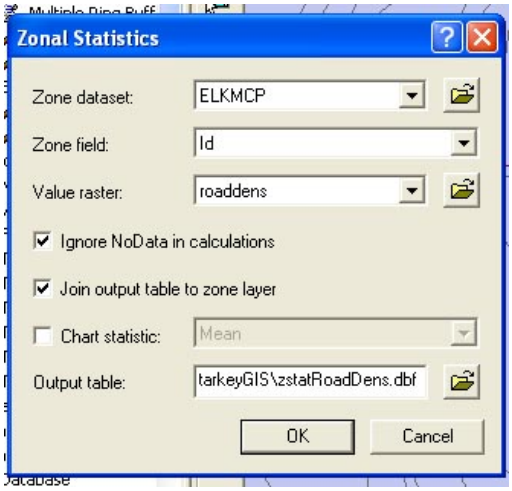


- Use the same process described above in Lines/Polygons to transpose your records.

Rasters

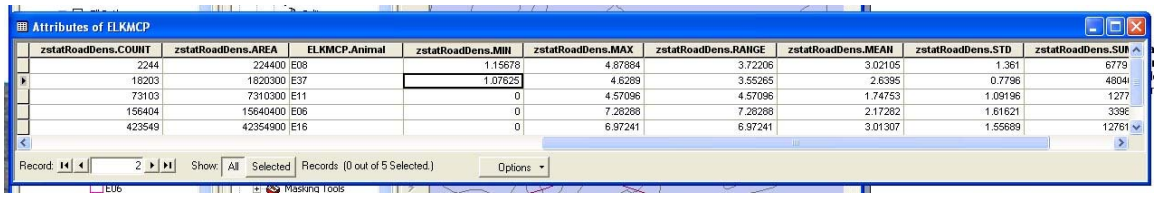
- Spatial Analyst/ Zonal Statistics

- Choose ELKMCP as the Zone dataset (to characterize habitat within a home range)



- It's important to use a descriptive filename here because the default field names are vague without this.

- Also note that this is only a temporary join to your original table. You can permanently join the info by choosing Data/Export after right clicking on the layer name in the TOC.



zstatRoadDens.COUNT	zstatRoadDens.AREA	ELKMCP.Animal	zstatRoadDens.MIN	zstatRoadDens.MAX	zstatRoadDens.RANGE	zstatRoadDens.MEAN	zstatRoadDens.STD	zstatRoadDens.SUM
2244	224400	E08	1.15678	4.87884	3.72206	3.02105	1.361	6779
18203	1820300	E37	1.07625	4.6289	3.55265	2.6395	0.7796	4804
73103	7310300	E11	0	4.57096	4.57096	1.74753	1.09196	1277
156404	15640400	E06	0	7.28288	7.28288	2.17282	1.61621	3396
423549	42354900	E16	0	6.97241	6.97241	3.01307	1.55689	12761

CREATE A MAP OF THE RELATIVE USE OF A MANAGEMENT AREA (RSF OR RUF).

After you have found the best model using appropriate model selection (e.g. AIC) and validation (e.g. k-fold cross validation) techniques we are now ready to apply the model to make spatially explicit predictions of resource selection. We will use a hypothetical RSF function to demonstrate this. Recall that RSFs generally have the form:

$$RSF = w(x) = \exp(\beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n)$$

1. To create our spatial RSF map we use the RASTER CALCULATOR in SPATIAL ANALYST:

- Click on Spatial Analyst > Raster Calculator to open the Raster Calculator form.
- Expand the Raster Calculator form by clicking on the “>>” button at the bottom of the form.
- Raster Calculator is very sensitive to syntax and spaces in the expressions you create. You can either use the buttons at the top and side of the form to create your expression, or you can type the expression directly into the lower window. Because of the complexity of the equation we are using it is suggested that you TYPE the expression yourself. The expression should look something like this:

exp(([starkey_dem] * 0.02902) - ([starkey_dem] * [starkey_dem] * 0.00001004) - ([diststrm] * 0.0000176) - ([roaddens] * 0.1124))

Note that you can use the scientific format for the coefficients if you prefer (this may be simpler if you used R to calculate them, as this is the format used by R):

exp(([starkey_dem] * 2.902e-02) - ([starkey_dem] * [starkey_dem] * 1.004e-05) - ([diststrm] * 1.760e-05) - ([roaddens] * 1.124e-01))
Note that we made these numbers up.

- When you have finished typing in the expression press the EVALUATE button. If you receive an error message (like “Failed to evaluate the calculator equation”) inspect your expression very carefully for syntax errors (missing spaces or signs or parentheses) until you are able to evaluate the expression.
- A new raster layer called “Calculation” will be added to your map. Click the check-mark box () next to that layer to switch it on. By default it will be

displayed in black and white. You can click the black-white strip next to that layer to change the color if you wish.

2. Standardize the RSF. Since the values produced by the RSF are arbitrary it is advisable to standardize the values, especially if you are comparing RSF models. Although there are a variety of methods we can use to standardize the values, one of the simplest is to simply scale the values from 0-1 using:

(RSF – minimum_value) / (maximum_value – minimum_value)

The maximum and minimum values are shown in the legend in ArcMap. Write those values down below:

Minimum RSF value: _____ Maximum RSF value: _____

In Raster Calculator, use the above expression to rescale your RSF from 0-1. Note that to reference the RSF layer you will need to use this expression: [Calculation]

Right click on Calculation2 and choose Make Permanent if you would like to keep the raster output. Rename it something more meaningful.