Conservation Landscapes: Adaptable GIS for ecologists and managers

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Short Course
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Abstract

A species of special concern is potentially threatened by resource development in its habitat, or is it? How to apply current spatial modelling methods to help address such ecological questions is demonstrated. Hands-on guided exercises delve further in to the out-of-the-box software functionality, work with custom open-source tools, and reveal a flexible workflow that may be tailored to many different taxa and ecosystems. The topics covered include landscape characterization (vegetation indices, satellite image classification, and change detection), management unit delineation (watersheds and home ranges), scenario modelling (shifting landscapes), temporal and proximity habitat analyses (date matching, cost paths, and network distances), and calculating the spatial map from regression-based equations (model calculation). While showcasing Alberta research examples, various effective strategies are shared for dealing with the numerous and/or large datasets associated with the pursuit of ecological investigations typical of conservationists worldwide. Note: Course participants are expected to be familiar with ArcGIS.

Venue
University of Alberta
North Campus, BioSci B118

Date
Thursday July 8th, 2010
4 hours

Prerequisite
Previous experience with ArcMap and Spatial Analyst

Based on Charlene Nielsen’s development of research solutions and educational materials on GIS in ecology at the University of Alberta http://www.biology.ualberta.ca/facilities/gis and supported in part by the Alberta Cooperative Conservation Research Unit (ACCRU) http://www.biology.ualberta.ca/accru
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Introduction

This is an applied short course on Geographic Information Systems (GIS) as leveraged in conservation biology and landscape ecology research at the University of Alberta. It involves versatile tools for landscape characterization, management unit delineation, scenario modelling, temporal and proximity analyses of habitat, and the calculation of spatial habitat maps from regression-based models.

Note that no statistical modelling is actually covered since this is a spatial course on developing the landscape layers (before and after) for use in such endeavours.

Alberta’s caribou, fish, grizzly bears, and simulated bird data are the example species, but the tools learned can be adapted to a wide diversity of research. Keep in mind that alternate tools/methods than what are presented here are available and potentially better suited. For example, the following third party extensions for ESRI ArcGIS:

MGET
http://code.env.duke.edu/projects/mget

HRT
http://www.blueskytelemetry.com/downloads.asp

GME
http://www.spatial ecology.com/gme

are excellent tools available for similar and additional specialized tasks.

However, the focus of this particular short course is to expand your command of the built-in tools for ESRI ArcGIS along with the freely transferable methods of working with the ModelBuilder and provided custom script tools from open source Python.
How to use this manual

The hands-on guided exercises of this short course are concerned solely with step 4 of the general steps of a GIS-based analysis as outlined below:

1. Identify your objective and determine the methods needed; e.g. how has the landscape changed between time periods in the caribou home range? home range type? classification algorithm? how to extract characteristics (simple proportions or landscape metrics)? It is often helpful to fit these methods that visualize the real world to the product needed – i.e. outline a cartographic model to make your workflow more efficient

2. Assemble data needed to prepare the spatial database; e.g. caribou locations, satellite imagery

3. Process existing data to get your ‘data ducks’ all lined up in a row; e.g. conversion, projection, extraction

4. Perform the analyses by following the steps under the appropriate tasks listed in this manual; e.g. the objective exemplified here could follow 3.2.2 >>> 2.2.1 >>> 2.3.2

5. Interpret and assess the results and prepare for presentation; e.g. export tables, map layouts, graphs
The manual and tool solutions are not meant to be followed in a linear fashion. Therefore, the ‘Sample workflows’ are provided for the most effective learning of how to complete step 4 described above. They guide you on how to analyze conservation landscapes – these are the data layers that form the foundation of spatial research in conservation biology and landscape ecology.

Acknowledgements

The following people kindly provided real-world sample location data: Foothills Research Institute – Gordon Stenhouse; University of Alberta – Scott Nielsen, Fiona Schmiegelow, Simon Slater, David Schindler and Erin Kelly!

In addition to Erin Kelly, Seth Cherry, Jodie Pongracz, Vicki Sahanatien, Brett Scheffers, Rebecca Rooney, Scott Nielsen, Cameron Aldridge, Kyle Knopff, Evelyn Merrill, Jacqui Frair, Barry Robinson, Nick Pilford, Lori Holmstol, Kerri Lappin, Simon Slater, Chris Carli, and Kim Dawe, the 440+ students, faculty, and colleagues associated with ACCRU have provided many interesting challenges and inspirations for the GIS solutions shared here.

ESRI’s ModelBuilder and Python-infused ArcGIS Desktop in conjunction with all the talented corporate and public folks associated with the following websites:

http://support.esri.com
http://forums.esri.com
http://forums.arcgis.com

are deemed invaluable for developing the solutions in analyzing conservation landscapes.
Sample workflows

The following examples are provided to guide you in choosing the set of tools needed to answer almost any conservation ecology question. Refer to the ‘Course data’ section below for access to the available data.

If your particular question is not detailed below, simply adjust and/or expand the most appropriate case using data and the order of methods/tools most pertinent to your research. Then work through the corresponding numbered sections.

Required inferential statistical methods to completely answer the questions are beyond the scope of this manual.

Don’t forget about incorporating the built-in ArcGIS geoprocessing tools as needed!

**Question 1**: How has the landscape changed within caribou KDE home ranges?

**Available Data**: landcover raster, multispectral satellite imagery, caribou locations

**Workflow**:
- Unsupervised classification of landcover
- Kernel density estimation of home range
- Percent contours from ASCII
- Layer change

**Question 2**: What is the percent composition of landcover within caribou MCP home ranges?

**Available Data**: landcover raster, multispectral satellite imagery, training sites, caribou locations

**Workflow**:
- Supervised classification of landcover
- Minimum convex polygon home ranges
- Binary rasters of each landcover class
- Zonal change or Overlap area sampling
Question 3: What are the vegetation characteristics within sub watersheds?
Available Data: multispectral satellite imagery and digital elevation model
Workflow:
- Equal sized watersheds
- Tassel cap
- Zonal change

Question 4: How does the landscape composition differ between catchments of fish sample locations?
Available Data: landcover raster, digital elevation model, fish locations
Workflow:
- Overlapping watersheds
- Binary rasters of each landcover class
- Overlap area sampling

Question 5: Before and after spatial layers for an individual grizzly bear habitat model...
Available Data: landcover raster, linear and point features, digital elevation model, grizzly bear locations
Workflow:
- Landcover proportions
- Measures per area
- Home range (MCP or KDE)
- Point sampling
- Statistical modelling (external software)
- Spatial model map

Question 6: What is the vegetation index value for each grizzly bear location by date?
Available Data: NDVI rasters and grizzly bear locations for same time series
Workflow:
- NDVI
- Date matched cell values
Question 7: How far are grizzly bear locations to the edge of higher vegetation biomass?
Available Data: NDVI rasters and grizzly bear locations for same time series
Workflow:
- NDVI
- Date matched contours

Question 8: How would simulated cutblocks affect forest bird habitat?
Available Data: landcover raster, cutblock plan, bird habitat
Workflow:
- Minimum convex polygon home range
- Random feature shifting inside habitat
- Update raster landscape
- Zonal change or Layer change

Question 9: Which bird nesting locations would be affected by the density of new roads to new cutblocks?
Available Data: existing human access, random cutblocks (from 8), landcover raster, bird locations
Workflow:
- Automatic linear features
- Measures per area
- Point sampling

Question 10: What are the functional distances between habitat patch edges before and after development?
Available Data: landcover raster, development features (cutblocks from 8 or roads from 9), habitat features, bird locations
Workflow:
- Update raster landscape
- Multiple cost paths
Course data

All the required data are in the SCB2010 folder.

The available data for each question number in the ‘Sample workflow’ identified above is contained inside a self-named folder. An additional geodatabase – AlbertaProvince.gdb – is provided for mapping.

It is recommended that the majority of the analyses be performed by accessing ArcToolbox via ArcCatalog (this will be faster because there is no redraw or screen refresh needed as in ArcMap). Also, for each new question set the global ArcToolbox environment to the provided empty WORK folder.

If working within ArcMap, note that some of the tools do not allow direct input from the layer in the map – in these cases examine the layer properties to learn the directory path(s) of the data required by the tool then navigate to the location using the browse button (open folder icon).

The ‘References’ section indicates the websites for the freely available spatial data used in this short course.

<table>
<thead>
<tr>
<th>Species</th>
<th>Questions</th>
<th>Year(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WC Caribou</td>
<td>1 and 2</td>
<td>2001/06</td>
</tr>
<tr>
<td>AR Fish</td>
<td>3 and 4</td>
<td>2008</td>
</tr>
<tr>
<td>WC Grizzly</td>
<td>5, 6, and 7</td>
<td>2000</td>
</tr>
<tr>
<td>AR Birds</td>
<td>8, 9, and 10</td>
<td>2008</td>
</tr>
</tbody>
</table>

*Note: Abbreviated study areas are WC for West-Central and AR for Athabasca River.*
ACCRU tools

The ACCRU Tools toolbox contains custom, ever-evolving tools created to answer ecological questions posed by researchers of the Alberta Cooperative Conservation Research Unit (ACCRU) at the University of Alberta.

Although specific applications in conservation ecology form the basis of tool development – e.g. temporal analysis of polar bear sea ice habitat, proximity analyses of urban amphibian wetlands, forest harvest block edge crossing characterization, wolf behavioural cluster identification, landscape randomization, a changeable habitat model calculator, and more – they are flexible enough for just about any ecologist's use.

Several generic utilities are also included to help make data processing and other workflows more efficient.

The open source of the Python language and ModelBuilder framework allows experienced users to modify the tools to help answer alternative questions.


INSTALL by unzipping the folder to the local drive and in ArcToolbox 9.3+ right-click to Add Toolbox, navigate to the local directory, select the ACCRU Tools.tbx file, and click Open.

VIEW THE HELP SIDEBAR FOR DETAILS AND TIPS ON ALL THE TOOL PARAMETERS!

The following numbered sections provide:
- a brief description of what each tool does
- the geoprocessing involved
- suggested use
1 General utilities

1.1 Add/calculate fields

1.1.1 Geometry Fields
- Add as appropriate the coordinates, length, and/or area
- *Add Field, Calculate Field*
- Apply to single or multiple features of any geometry to automate the adding and calculating of shape geometry field(s); especially useful for shapefiles or if you wish to compare original geometries with overlay results; e.g. intersected areas with original whole areas; can choose common or all available geometries

1.1.2 Special Fields
- Add user-specified file name, constant, and/or random
- *Add Field, Calculate Field*
- Up to three fields including the file name (handy for identifying the source), a numeric or text-based constant (useful for indicating metadata), or random (can then be selected for random sub setting) are calculated; constant and/or random may become input field(s) for other tools

1.1.3 Cumulative Fields
- Add user-specified unique identifier, group, or successively adds values from user-selected existing field
- *Add Field, Calculate Field*
- Up to three fields including a unique integer identifier (hard coded version of the object ID), a sequential set of grouping values, or cumulated values based on an existing numeric field are calculated; may become input field(s) for other tools

1.1.4 Convert Date Field
- Formats date to specified text string
- *Add Field, Calculate Field*
- Useful for tools 4.1.1 and 4.1.2
1.2 Combining/separating

1.2.1 Merge With Filename
- User specifies geometry or table type used to add file name field prior to merging from input workspace
- Add Field, Calculate Field, Merge
- Same as the built-in tool but automatically calculates the file name to all inputs so the features can be linked back to their source and/or used as unique or grouping identifiers

1.3 Table manipulations

1.3.1 Export To CSV
- Convert attribute and standalone tables to comma separated values text file format
- Make Table View
- A quick way to export any single or multiple table(s) to the format accessible by R, Excel, and many other external software packages

2 Landscape characterization

2.1 Vegetation indices

2.1.1 NDVI
- Normalized Difference Vegetation Index calculated by user-specified satellite bands
- Single Output Map Algebra
- Provides tips on the typical near-infrared and red inputs for common satellite sensors to create the vegetation index.

2.1.2 Tassel Cap
- Brightness, greenness, wetness transformations calculated by user-specified sensor and bands
- Single Output Map Algebra
- Simply specify the supported satellite sensor and the tool uses the appropriate set of coefficients drawn from published scientific literature (see script comments).
2.2 Categorical classification

2.2.1 Supervised Classification
- Apply the input features sampling file to a set of raster bands, create the signature file, and perform maximum likelihood classification
- Create Signatures, Maximum Likelihood Classification
- Quickly classify multispectral satellite imagery to a landcover product using training data

2.2.2 Unsupervised Classification
- Apply the isodata clustering algorithm to a set of raster bands, create the signature file, and perform maximum likelihood classification
- Iso Cluster, Maximum Likelihood Classification. Get Raster Properties, Add Field, Calculate Field
- Quickly classify multispectral satellite imagery to a landcover product using statistical groupings

2.2.3 Binary Class Conversions
- Convert each class value to a binary raster of 1s and 0s
- Con, Get Raster Properties
- Useful for tools 2.3.2 and 7.1.2

2.3 Change detection

2.3.1 Layer Change
- Proportion changed between all unique pair input rasters
- Combine, Add Field, Calculate Field
- Optionally generate unique pair rasters

2.3.2 Zonal Change
- Summary statistics for multiple rasters representing different time periods and copies the selected statistic to the attribute table of the input zones
- Zonal Statistics As Table
- Can be any set of rasters in the input folder; additional statistics in the output tables
2.4 Continuous landscapes

2.4.1 Proportions
- Relative amount of each raster category within a user-specified neighborhood
- *Make Table View, Single Output Map Algebra*
- Efficiently extract proportions of categorical data for spatial model sampling

2.4.2 Measures Per Area
- Line length per area or point count per area within a user-specified radius
- *Multi Output Map Algebra, Polygon To Line (if ArcInfo license available)*
- Any geometry is accepted and the appropriate command is applied: PointStats() for point inputs and LineStats() for line and polygon input; this yields number of points per area or map units per square map units for edge density

3 Management unit delineation

3.1 Watersheds

3.1.1 Equal Sized Watersheds
- Create raster/features of approximately similar-area sub watersheds using a threshold value
- *Con, Stream Link, Watershed, Stream To Feature, Raster To Polygon*
- Use this tool to divide up the study area based on topography and drainage; may need to experiment with the threshold value

3.1.2 Overlapping Watersheds
- Create raster and polygon watershed features for each input drainage locale
- *Make Table View, Feature To Raster, Copy Raster, Single Output Map Algebra, Raster To Polygon, Merge*
- Use this tool when you have specific drainage points, lines, or polygons (e.g. entire water bodies) that may or may not overlap with their neighbours; the Select()
and Watershed() commands are created automatically based on the object ID or value field of the input drainage data

### 3.1.3 Watershed Inputs
- Automate required inputs for the above watershed tools
- *Fill, Flow Direction, Flow Accumulation*
- Automate!

### 3.2 Home ranges

#### 3.2.1 Minimum Convex Polygon
- MCP(s) for entire set or each group subset of points – these are essentially maximal areas of observed locations
- *Copy Features, Add Field, Make Table View*
- Easily accessible for modification and incorporation in to other workflows; the purely Python convex hull functions credited to Dinu C. Gherman

#### 3.2.2 Kernel Density Estimation
- Under construction! Will call an R script that uses the Plug-In method for estimating utilization distribution(s) based on a probability density estimation – these are essentially probable areas of observed locations
- See R subfolder in ACCRU_Tools folder for the operational kde_loop_by_unique_ID.R and _kde_instructions.txt files

#### 3.2.3 Percent Contours From ASCII
- Convert ASCII to raster grid and creates percent value contour features
- *ASCII To Raster, Define Projection, Get Raster Properties, Contour List, Add Field, Calculate Field, Make Feature Layer, Merge*
- Creates percent value contours as lines and polygons from input kernel density estimation ASCII files
4 Temporal analyses

4.1 Date matching

4.1.1 Date Matched Cell Values
- Intersect points with rasters by matching date
- *Add Field, Calculate Field, Get Cell Value*
- This is useful for extracting the correct raster cell values for each point location by time

4.1.2 Date Matched Contours
- Distance to selected contours – edge by time
- *Add Field, Calculate Field, Copy Features, Contour List, Select, Near, Merge*
- This is useful for identifying a boundary based on user-specified criteria for continuous surfaces; e.g. elevation, vegetation index, percent composition, sea ice concentration, climate, etc. for rasters of multiple time periods

5 Proximity analyses

5.1 Multiple paths

5.1.1 Multiple Cost Paths
- Multiple edge-to-edge distances between any combination of two feature datasets via least accumulative cost raster values
- *Get Count, Make Feature Layer, Cost Distance, Cost Path, Make Table View, Raster To Polyline, Add Field, Calculate Field, Merge, Dissolve*
- This is useful for calculating the functional distances between area features such as habitat patches and water bodies; any combination of points, lines, or polygons can be used for the starting and target features; if single input then unique pair paths are calculated (A to B, A to C, B to C)
5.2 Multiple buffer landscapes

5.2.1 Multiple Ring Landscapes
- Automate multiple buffer 'rings' and optionally extract landcover proportions for each feature
- Make Feature Layer, Multiple Ring Buffer, Add Field, Calculate Field, Dissolve, Intersect, Merge, Feature Class To Feature Class
- This is useful for creating multiple buffer rings and extracting landcover information for each

5.2.2 Buffered Landscapes To Raster
- Convert the multiple ring landscapes to rasters while simultaneously writing the batch file for FragStats analyses
- Add Field, Calculate Field, Make Table View, Select, Feature To Raster
- Automates the conversion of the output from tool 5.2.1

6 Scenario planning

6.1 Feature shifting and creation

6.1.1 Random Feature Shifting
- Move a copy of input polygons to random locations
- Get Count, Add Field, Calculate Field, Create Random Points, Add XY, Copy Features
- Can do so within extent of a base layer such as landcover for the study area; optionally, do so within a ‘mask’ to disallow placement inside private land or other known areas of conservation interest

6.1.2 Automatic Linear Features
- Systematic creation of roads/etc. between all input features
- Cost Distance, Cost Path, Raster To Polyline, Dissolve
- Useful for planning the connection of new development features with existing roads
6.1.3 Move Points By Calculated Fields
- Move input point locations by user-specified random/constant values for distance and bearing
- Add Field, Calculate Field, Add XY, Make XY Event Layer, Copy Features
- Useful for simulations and field sampling protocols

6.1.4 Move Points By Existing Fields
- Move input point locations using values in existing fields for distance and bearing
- Add XY, Make XY Event Layer, Copy Features
- Useful for simulations and field sampling protocols

6.2 Update landscape

6.2.1 Update Raster Landscape
- Convert features and overlay on existing categorical raster
- Add Field, Calculate Field, Get Raster Properties, Feature To Raster, Single Output Map Algebra
- Useful for simulations and updating old data

7 Habitat model calculation

7.1 Sampling

7.1.1 Point Sampling
- Intersect points with above landscapes
- Add Field, Get Cell Value
- Similar to the built-in Sample tool but does not require Spatial Analyst and appends new fields to input attribute table

7.1.2 Overlap Area Sampling
- Summary statistics for overlapping features for multiple rasters
- Create File GDB, Make Feature Layer, Zonal Statistics As Table, Merge
- Deals with overlapping zones (e.g. watersheds) for a single or multiple raster(s)
7.2 Spatial model

7.2.1 Spatial Model Map

- Raster model output based on habitat selection/RSF equation; requires an explicitly formatted input table of logistic regression beta coefficients
- **Make Table View, Single Output Map Algebra, Con**
- Automates the calculation of a logistic regression model for one or two raster variables; a table displaying the coefficients and variables is already needed for most manuscripts so simply convert to a format supported by ArcGIS (see example SMM_Input_Table.xls in Doc folder)
References


