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A Conservation Ecology Toolbox

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Abstract
The ACCRU Tools toolbox contains custom, ever-evolving tools created to answer ecological questions posed by researchers of the Alberta Conservation Cooperative 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, etc. – 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.

1 Introduction

The Department of Biological Sciences at the University of Alberta, Edmonton, Alberta, Canada, has approximately 80 researchers each year who integrate GIS, remote sensing, and satellite telemetry to improve or develop alternative methods used in their ecosystem and wildlife investigations (http://www.biology.ualberta.ca/facilities/gis). The majority of the faculty and aspiring graduate student ecologists are associated with the Alberta Conservation Cooperative Research Unit (ACCRU) – a multi-disciplinary, inter-departmental, and multi-institutional research and learning centre (http://www.biology.ualberta.ca/accru).

The extensiveness of GIS involved in the terrestrial and aquatic ecology research projects is dependent on the individual needs: some researchers simply visualize spatial patterns of their collected field data while others require complex modelling. Often, the quantity of data that must be quantified is so numerous that automated batch solutions are definitely desired. Or, the basic out-of-the-box functionality of the GIS software cannot fully address the task at hand. Over the years, the vast and varied projects (see 'Sample research cases' below) have generated multiple new custom GIS tools.

2 Sample research cases

The species, study area, and available data are some of the complexities that must be addressed when analyzing ecological questions using GIS. The following summarizes the wide array of these by describing just a sampling of projects in the BioSciences at the University of Alberta (there are far too many to include here). The specific ACCRU tool name(s) that evolved from the research are listed below each.

Full citations of completed theses and dissertations mentioned here are listed at http://www.biology.ualberta.ca/facilities/gis/?Page=3063.

2.1 Catchments

Erin Kelly's dissertation analyzed the extent of atmospheric mercury contamination and bioaccumulation in the alpine lakes of the Rocky Mountains (*multiple species, supervised by Dr. David Schindler*). As a post-doctoral researcher she applied similar analyses to assessing pollution levels (*heavy metals and polycyclic aromatic compounds in air, water, and organisms*) from oil sands operations in the lower Athabasca River watershed. The GIS methods involved in both studies required massive datasets to cover the large extents, including reliable digital elevation models for delineating complete catchments, including overlapping areas, for each sampling location.

ACCRU Tools: 3.1.2 Overlapping Watersheds, 7.1.2 Overlap Area Sampling

2.2 Wetland surroundings

The proximity of the various terrestrial ground cover types and land uses to aquatic habitats is a crucial consideration in many wetland studies, including those by Brett Scheffers (*urban amphibians, MSc supervised by Cindy Paszkowski*) and Rebecca Rooney (*monitoring and evaluating wetland reclamation in the oil sands, PhD supervised by Suzanne Bayley*). Built-in ArcGIS tools for buffering, overlays, and distance analyses are quite useful as is, but in some instances need to be automated for a multitude of study sites, or extended to perform more specialized analyses, such as dispersal; e.g. calculating the edge-to-edge distances between breeding ponds and available habitat patches was not a ready-made tool.

ACCRU Tools: 5.1.1 Multiple Cost Paths, 5.2.1 Multiple Ring Landscapes, 5.2.2 Buffered Landscapes To Raster

2.3 Dynamic sea ice habitat

The daily changing environment of polar bears studied by researchers in Andy Derocher's lab (*Vicki Sahanatien, PhD, Jodie Pongracz, MSc, and Seth Cherry, PhD*) requires coordinating the date of locations with corresponding sea ice data. The animal coordinates are recorded via telemetry as often as once a day and the remotely-sensed products of sea ice concentrations are provided daily, weekly, or bi-monthly. The corresponding date of each point must be matched (and in some cases reclassified to conform to existing ice dates) to extract the ice chart values. The tools can easily be adapted to time series analysis of data representing other habitat characteristics, such as vegetation indices.

ACCRU Tools: 4.1.1 Date Matched Cell Values, 4.1.2 Date Matched Edges, 7.1.1 Point Sampling

2.4 Home ranges

An extremely common analytical method in wildlife research is to spatially map the probable area of a species' activity. Among others in the BioSciences, recent researchers utilizing home ranges have included Kyle Knopff (*cougars, PhD supervised by Mark Boyce*), Nick Pilford (*caribou, independent study supervised by Stan Boutin*), Lori Homstol (*black bears, MSc supervised by Colleen Cassidy St. Clair*), and Barry Robinson (*elk, MSc supervised by Evelyn Merrill*). Excellent third party extensions (Home Range Tools and Geospatial Modelling Environment) also exist for creating home ranges as minimum convex polygons (MCPs) and kernel density estimations (KDEs: a.k.a. utilization distributions). However, ACCRU research has required batch processing with random iterations (MCPs) or alternative bandwidth selection techniques (KDEs) that is not available in the alternative software.

ACCRU Tools: 1.2.1 Merge With Filename, 1.3.1 Export To CSV, 3.2.1 Minimum Convex Polygon, 3.2.2 Kernel Density Estimation

2.5 Edge crossing characterization

Quantifying what vegetation types are commonly crossed by an ungulate (*Evelyn Merrill*) or how often a grizzly bear enters and leaves a forest harvest cutblock (*Terry Larsen, MSc supervised* *by Erin Bayne*) can be examined by simply intersecting lines and polygons to output the coincident point attributes. ModelBuilder or Python scripting streamlines the multiple steps that achieve these calculations.

ACCRU Tools: 8.1.1 Edge Crossing

2.6 Animal behavioural cluster identification

When retracing GPS telemetry locations of wildlife, various researchers, including Peter Knamiller (*wolves, MSc supervised by Evelyn Merrill*), have needed to identify groupings of locations that might indicate behaviour, such as denning or foraging sites. Time, space, and temporal resolution of the data collected must be considered.

ACCRU Tools: 4.2.1 Cluster By Criteria

2.7 Scenarios for simulating landscapes

Many opportunities exist with GIS to generate future or alternate landscapes. Kerri Lappin's master's project (*MSc supervised by Lee Foote*) involved random placement of theoretical wetlands in a coal reclamation area. A script applied to the polygon shape attribute within ModelBuilder did the trick. The author also assisted Scott Nielsen's extensive work with the Great Sand Hills Environmental Study, Saskatchewan, http://www.environment.gov.sk.ca/2007-104GreatSandHillsEnvironmentalStudy). Part of the study analyzed how the biodiversity may be affected by the introduction of more oil/gas wells. The methods developed for the new associated roads simulation has since been automated.

ACCRU Tools: 6.1.1 Random Feature Shifting, 6.1.2 Automatic Linear Features, 6.2.1 Update Raster Landscape

2.8 Various mapping and modeling

Data files for input in to the landscape metrics package FragStats (*Evelyn Merrill, Rebecca Rooney*), streamlining satellite image classification (*Chris Carli, MSc supervised by Suzanne Bayley*), pre- and post- habitat modelling via regression-based statistical methods (*Jacqui Frair, Evelyn Merrill, Scott Nielsen, Cameron Aldridge*), extracting zonal statistics for multiple rasters (*Scott Nielsen, Erin Kelly*), processing large numbers of climate grids (*Kim Dawe, PhD supervised by Stan Boutin*), calculating vegetation indices (*many*), and batch processing data conversions (*many*) are among the additional solutions incorporated in to the collection of ACCRU Tools.

ACCRU Tools: 1.1.1 Geometry Field, 1.1.2 Special Field, 1.1.3 Cumulative Field, 1.3.2 Summarize Multiple Fields, 2.1.1 NDVI, 2.1.2 Tassel Cap, 2.2.1 Supervised Classification, 2.2.2 Unsupervised Classification, 2.3.2 Binary Class Conversions, 2.3.1 Layer Change, 2.4.1 Proportions, 2.4.2 Measures Per Area, 5.3.1 Distances Along Network, 7.1.1 Point Sampling, 7.2.1 Spatial Model Map

3 Software

3.1 Open flexible applications

ESRI **ArcGIS Desktop 9.3.1** (http://www.esri.com) may not have the specialized tools designed explicitly for conservation ecology research, but it has all the basic building blocks necessary for analyzing spatial data in more than one way. Mobilization, automation, and extension via a programming language are all that is needed. COM-compliant programming languages that can be compiled were not chosen for the ACCRU Tools toolbox because they prevent modification, customization, and updateability by other users without access to the source code. Also, the backwards compatibility of third-party extensions for ArcGIS and other software using such programming languages is frequently an issue with each new major software release. Therefore, the free and open source **Python 2.5** (http://www.python.org), wholly supported by ESRI, is the most logical choice. The author must continually deal with all these issues and also subscribes to the notion that 'free and easy' is always better. Python has proven to be the perfect way to most effectively link, leverage, and expand upon the built-in geoprocessing tools for a variety of research solutions.

The "free software environment for statistical computing and graphics" **R 2.10** (http://www.r-project.org) is gradually being incorporated in to the toolbox. The 3.2.2 Kernel Density Estimation tool is currently the only tool to access the powerful statistical methods of R.

3.2 Licensing requirements

The majority of the ACCRU Tools are accessible via an ArcView license.

However, two tools require an ArcInfo license because they access the functionality of the Near tool: 4.1.2 Date Matched Edges and 5.1.1 Multiple Cost Paths.

The following tools require the Spatial Analyst extension: 2.1.1 NDVI, 2.1.2 Tassel Cap, 2.2.1 Supervised Classification, 2.2.2 Unsupervised Classification, 2.2.3 Binary Class Conversions, 2.3.1 Layer Change, 2.3.2 Zonal Change, 2.4.1 Proportions, 2.4.2 Measures Per Area, 3.1.1 Equal Sized Watersheds, 3.1.2 Overlapping Watersheds, 4.1.2 Date Matched Edges, 5.1.1 Multiple Cost Paths, 6.1.2 Automatic Linear Features, 6.2.1 Update Raster Landscape, 7.1.1 Point Sampling, 7.1.2 Overlap Area Sampling, 7.2.1 Spatial Model Map.

Only one tool requires the Network Analyst extension: 5.3.1 Distances Along Network.

3.3 Disclaimer

These tools were developed for specific research applications and the University of Alberta provides no warranty of their results. It is up to the user to ascertain quality and appropriate format of their input data and verify all outputs and results.

4 How to use the toolbox

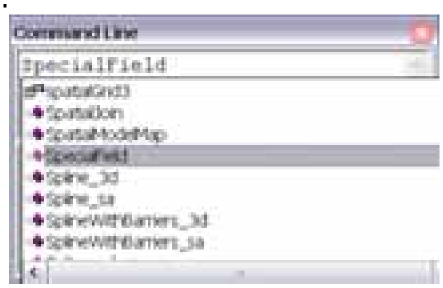
4.1 Acquisition

To access and download the freely available ACCRU Tools visit the following web page: http://www.biology.ualberta.ca/facilities/gis/?Page=3063.

Because the ACCRU Tools is a toolbox, the individual tools are readily available for use in:

- lengthier workflows set up in ModelBuilder (connect to other tool inputs/outputs) and
- built-in batch processing of ArcToolbox (simply right-click on the tool and click Batch…).

The **label** of each tool is prefixed by a categorical numbering system (see 'Structure and description…' below). This allows for efficient indexing and searching in ArcToolbox. The numbering is not necessarily meant to be followed in a linear fashion.



Command Line and Python scripting references the basic tool **name** (i.e. does not have the numbering prefix).

4.2 Workflows

To use the tools (after identifying the research objectives, assembling the spatial database, and processing the files) fit the custom tools together for complete conservation ecology workflows. The following are example research questions that may be addressed (refer to the handy numbering displayed in 'Structure and description…' and the 'Appendix'):

What is the percent composition change of landcover within caribou MCP home ranges?

- 2.2.2 >>> 3.2.1 >>> 2.2.3 >>> 2.3.2

What are the vegetation characteristics within the catchment of fish sampling locations?

- 3.1.2 >>> 2.1.2 >>> 7.1.2

What is the correct sea ice concentration value for each polar bear location by date?

- 4.1.1

How far are polar bear locations to the edge of specified sea ice concentrations?

- 4.1.2

Before and after spatial layers for an individual elk/grizzly bear/ sage grouse habitat model:

- 2.4.1 >>> 2.4.2 >>> 7.1.1 >>> Statistical Software >>> 7.2.1

Can random wetlands help with coal mining reclamation planning?

- 6.1.1 >>> 6.2.1

How would the density of new roads to new well pads affect biodiversity?

- 6.1.2 >>> 2.4.2 >>> 7.1.1

What is the difference between straight-line and functional distances between amphibian breeding ponds and native habitat patch edges?

- 5.1.1

4.3 Tips for modification/customization

Any desired custom changes are accessible because the tools themselves are:

- ModelBuilder constructs that can easily be reconfigured with different parameters and variables (see ArcGIS Desktop Help, especially http://webhelp.esri.com/arcgisdesktop/9.3/index.cfm?TopicName=Managing_parameters) or
- open Python code (see ArcGIS Desktop Help, especially http://webhelp.esri.com/arcgisdesktop/9.3/index.cfm?TopicName=Understanding_script_tool_parameters).

The convention for identifying arguments, automating variables and environment settings is to specify these as variables at the top of the *.py code file where anyone can quickly modify as needed: probing through the entire code is not necessary unless one wants to completely rewrite the functionality.

5 Structure and description of ACCRU Tools

See the 'Appendix' for a graphical representation of the toolbox. Below is a summary of each custom tool, presented by its order in the toolbox. Tool-specific licensing requirements beyond the core ArcView level are italicized in the 'Geoprocessing Involved' column.

5.1 General utilities

Subcategory	Label Prefix	Tool	Geoprocessing Involved	Description
1.1 Add/Calculate Fields	1.1.1	Geometry Field	Add Field, Calculate Field	Adds a user-specified field name and calculates new field values for either COORDINATES (point coordinate, line mid-/start-/end-point, polygon centroid), LENGTH (line, polygon perimeter), or AREA (polygon only)
	1.1.2	Special Field	Add Field, Calculate Field	Adds the user-specified field name and calculates one of the selected values: file name (text), unique ID (long integer), or random (double)
	1.1.3	Cumulative Field	Add Field, Calculate Field	Adds the user-specified field name and calculates the cumulative values in to the new field based on the user-specified existing field

Subcategory	Label Prefix	Tool	Geoprocessing Involved	Description
1.2 Combining	1.2.1	Merge With Filename	Add Field, Calculate Field, Merge	Selects all user-specified geometry (point, line, polygon, or table file type) from the input folder and merges in to one file where a new attribute field identifies the original source file name; optionally, can filter by a wildcard string
1.3 Table Manipulations	1.3.1	Export to CSV	Python processing	Exports user-specified input table to a comma separated values text file
	1.3.2	Summarize Multiple Fields	Summary Statistics, Add Field, Calculate Field, Delete Field	Generate output table of summary statistics for input file based on two or more user-specified fields

5.2 Landscape characterization

Subcategory	Label Prefix	Tool	Geoprocessing Involved	Description
2.1 Vegetation Indices	2.1.1	NDVI	*SPATIAL ANALYST* Single Output Map Algebra	Normalized Difference Vegetation Index (NDVI) calculated by user-specified sensor type and bands
	2.1.2	Tassel Cap	*SPATIAL ANALYST* Single Output Map Algebra	Tassel cap transformations - brightness, greenness, wetness - calculated by user-specified sensor and bands
2.2 Categorical Classification	2.2.1	Supervised Classification	*SPATIAL ANALYST* Buffer, Feature Envelope To Polygon, Create Signatures, Maximum Likelihood Classification	Applies the input features sampling file to a set of raster bands, creates the signature file, and performs maximum likelihood classification; if input features are points or lines then the optional buffer value can be used to expand their 'footprints'
	2.2.2	Unsupervised Classification	*SPATIAL ANALYST* Iso Cluster, Maximum Likelihood Classification	Applies the isodata clustering algorithm to a set of raster bands, creates the signature file, and performs maximum likelihood classification
	2.2.3	Binary Class Conversions	*SPATIAL ANALYST* Single Output Map Algebra (Con)	From the input categorical raster, create multiple new binary rasters where values of 1 indicate presence of each class and 0 for all else; saved to new output folder using values in the specified field for the output names (integers will be prefixed by the letter 'b')
2.3 Change Detection	2.3.1	Layer Change	*SPATIAL ANALYST* Subtract, Combine	Select the option to subtract two layers or combine two or more layers for analyzing differences
	2.3.2	Zonal Change	*SPATIAL ANALYST* Zonal Statistics As Table	Calculates summary statistics for multiple rasters representing different time periods (or any set of rasters in the input folder)

Subcategory	Label Prefix	Tool	Geoprocessing Involved	Description
2.4 Continuous Landscapes	2.4.1	Proportions	*SPATIAL ANALYST* Single Output Map Algebra (Con and FocalMean)	Calculates the relative amount of each raster category within a user-specified radius
	2.4.2	Measures Per Area	*SPATIAL ANALYST* Single Output Map Algebra (LineStats or PointStats)	Calculates line length per area or point count per area within a user-specified radius

5.3 Management unit delineation

Subcategory	Label Prefix	Tool	Geoprocessing Involved	Description
3.1 Watersheds	3.1.1	Equal Sized Watersheds	*SPATIAL ANALYST* Fill, Flow Direction, Flow Accumulation, Con, Stream Link, Watershed	From input DEM, creates polygon features for approximately similar-area sub watersheds
	3.1.2	Overlapping Watersheds	*SPATIAL ANALYST* Fill, Flow Direction, Flow Accumulation, [Snap Pour Points,] Watershed	From input DEM, creates polygon watershed features for each input drainage feature
3.2 Home Ranges	3.2.1	Minimum Convex Polygon	Python processing	Creates polygon feature(s) that encloses the input points; analogous to a 'rubber band' snapped to the outermost perimeter of all coordinates
	3.2.2	Kernel Density Estimation	R processing, ASCII To Raster	Calls an R script that uses the Plug-In method for estimating utilization distribution(s) based on a probability density estimation

5.4 Temporal analyses

Subcategory	Label Prefix	Tool	Geoprocessing Involved	Description
4.1 Date Matching	4.1.1	Date Matched Cell Values	Get Cell Values	Extracts the correct raster cell values to each point location in time
	4.1.2	Date Matched Edges	*ARC INFO* Contour List, Near	Calculates distance(s) to user-specified boundary criteria for continuous raster surfaces to each point location in time

Subcategory	Label Prefix	Tool	Geoprocessing Involved	Description
4.2 Time With Space	4.2.1	Cluster By Criteria	Add Field, Calculate Field, Add XY Coordinates, Summary Statistics, Add Join Select, Delete	Identify groupings of locations that might indicate behaviour, such as denning or foraging sites. Optimizes by closest in time and space.

5.5 Proximity analyses

Subcategory	Label Prefix	Tool	Geoprocessing Involved	Description
5.1 Multiple Paths	5.1.1	Multiple Cost Paths	*ARC INFO* Near, Add Field, Calculate Field, Make XY Event Layer, Make Feature Layer (selection expression), Feature To Raster, Cost Distance, Cost Path, Raster To Polyline, Add Field, Calculate Field, Merge	Multiple edge-to-edge distances between any combination of two feature datasets (points, lines, polygons) via least accumulative cost raster values
5.2 Multiple Buffer Landscapes	5.2.1	Multiple Ring Landscapes	Buffer, Intersect, Dissolve	Create multiple buffer 'rings' and extract landcover proportions for each set of user-specified unique buffer ID, ring distance, and landcover class
	5.2.2	Buffered Landscapes To Raster	Select, Feature To Raster	Converts the output from Multiple Ring Landscapes to rasters along with a handy *.fbt batch file for FragStats analyses
5.3 Network Distances	5.3.1	Distances Along Network	*NETWORK ANALYST* Build Network, Make OD Cost Matrix Layer, Solve	Measure true distances between all input locations along a river or other network; automates Network Analyst's OD Cost Matrix solution

5.6 Scenario planning

Subcategory	Label Prefix	Tool	Geoprocessing Involved	Description
6.1 Feature Shifting and Creation	6.1.1	Random Feature Shifting	Copy Features, Calculate Field	Moves input features (points, lines, or polygons) to random locations within extent of a base layer (typically, landcover for the study area); optionally, do so within a mask to disallow placement inside private or other areas (note: current tool is not fully error-free when randomly placing lines and polygons)
	6.1.2	Automatic Linear Features	*SPATIAL ANALYST* Cost Distance, Cost Path, Raster To Polyline	Systematically creates linear features (i.e. roads) connecting all input features (points, lines, and/or polygons); user can specify up to two existing input layers
6.2 Update Landscapes	6.2.1	Update Raster Landscape	*SPATIAL ANALYST* Feature To Raster, Con	Converts input features and overlays on a user-specified categorical raster; assumes the user has calculated non-conflicting values in the feature's reclass field

5.7 Habitat model calculation

Subcategory	Label Prefix	Tool	Geoprocessing Involved	Description
7.1 Sampling	7.1.1	Point Sampling	*SPATIAL ANALYST* Sample, Add Join, Add Field, Calculate Field, Delete Field	'Intersect' input points with all rasters contained in the input folder; uses each raster name as new column headings
	7.1.2	Overlap Area Sampling	*SPATIAL ANALYST* Select, Zonal Statistics As Table	Extracts the zonal statistics for all input polygons even if they overlap
7.2 Spatial Model	7.2.1	Spatial Model Map	*SPATIAL ANALYST* Single Output Map Algebra	Applies the values from an explicitly formatted input table that specifies the coefficients and all other parameters of a regression model and applies to the corresponding rasters in the input folder; optionally, restrict the extent of analyses

5.8 Specialized

Subcategory	Label Prefix	Tool	Geoprocessing Involved	Description
8.1 Overlay Analyses	8.1.1	Edge Crossing	Intersect, Multipart to Singlepart, Dissolve, Summary Statistics	Intersects lines and polygons to output the coincident point attributes to quantify how often and what polygon class(es) are commonly crossed by an organism

6 Summary and future directions

The ACCRU Tools toolbox is the ever-evolving collection of tools designed and redesigned for specific applications in conservation ecology. The open-source framework is essential to sharing with everyone and provides future flexibility in the dynamic world of wildlife, fisheries, and ecosystem research. It is the widely differing experiences with ACCRU researchers that exemplify that what may solve a conservation ecology problem today will most definitely need to be fine-tuned for tomorrow.

The future of ACCRU Tools includes code optimization, updating to ArcGIS Desktop 10 (however, the improvements with this release may cause some ACCRU tools to be redundant), and eventually compatibility with Python 3.0. Additional tools are always under development.

7 Acknowledgements

Thank you to ESRI for reviving ModelBuilder and infusing ArcGIS Desktop with Python. All the talented folks (both corporate and public) associated with the http://support.esri.com, http://forums.esri.com, and http://forums.arcgis.com websites are invaluable resources. Special mention must go to Barry Robinson for sharing his R methods for kernel density estimation using the plug-in method. In addition to the specific researchers mentioned in the 'Sample research cases' section, I am appreciative of the many interesting challenges and inspirations provided by the 440+ students, faculty, and colleagues I have had the satisfaction of sharing my GIS skills with since 2001.

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9 Author Biography

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Appendix – Screen capture of the ACCRU Tools toolbox