

Linkage Mapper Toolbox: Pinchpoint Mapper User Guide

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Acknowledgements

Pinchpoint Mapper builds on much of the Python code developed with **Darren Kavanagh** for Linkage Pathways Tools, and uses Circuitscape, developed with **Viral Shah**. I am grateful for Darren and Viral’s excellent contributions.

Software Requirements and Licensing

Pinchpoint Mapper requires **ArcGIS Desktop** (10.3 or greater) or **ArcGIS Pro**, with the **ArcGIS Spatial Analyst** extension. **Circuitscape 4** must also be installed on your machine. This software is provided free of charge and is licensed under a GNU General Public License.

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1 Introduction

Pinchpoint Mapper is part of the Linkage Mapper toolbox, which includes the Linkage Pathways Tool (McRae and Kavanagh 2011) and other modules designed to support regional wildlife habitat connectivity analyses. Once corridors have been mapped using the Linkage Pathways Tool, Pinchpoint Mapper runs Circuitscape (McRae and Shah 2009) within the resulting corridors. This produces current maps that identify and map pinch points (i.e. constrictions, a.k.a. bottlenecks or choke points) in least-cost corridors. It also provides corridor effective resistance values, a measure of connectivity that complements least-cost distances.

More details on the theory behind this approach and on Circuitscape software can be found in McRae et al. (2008) and McRae and Shah (2009) respectively.

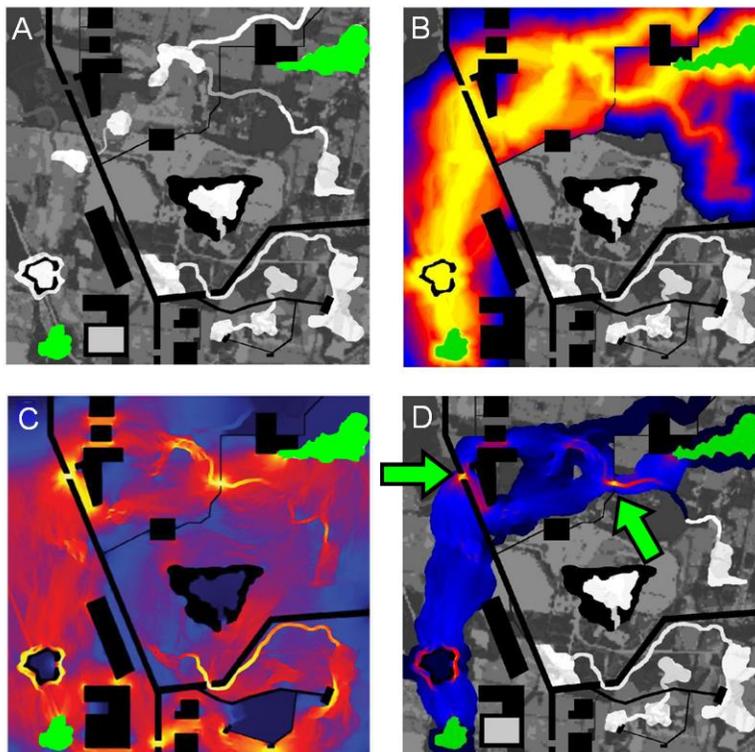


Figure 1. Example of how Pinchpoint Mapper can be used to identify and prioritize important areas for connectivity conservation. (A) Simple landscape, with two patches to be connected (green) separated by a matrix with varying resistance to dispersal (low resistance in white, higher resistance in darker shades, and complete barriers in black). (B) Least-cost corridor between the patches (lowest resistance routes in yellow, highest in blue). (C) Current flow between the same two patches derived using Circuitscape, with highest current densities shown in yellow (from McRae et al. 2008). Circuit analyses complement least-cost path results by identifying important alternative pathways and “pinch points,” where loss of a small area could disproportionately compromise connectivity. (D) Results from Pinchpoint mapper, which constrains current flow to the best

corridor. This approach hybridizes least-cost corridor and circuit theory approaches, showing both the most efficient movement pathways and critical pinch points within them. These could be prioritized over areas that contribute little to connectivity, such as the dark blue “corridor to nowhere” at the top right.

2 Installation

1) Install the latest version of Linkage Mapper

Follow the instructions in the Linkage Pathways Tool User Guide to install the toolbox.

2) Install version 4 of Circuitscape

The most recent and stable version of Circuitscape 4 (v4.07) is available as raw code on Github and here as a zip file install package: https://drive.google.com/file/d/1Pj_PUgbmZ1d97M_F0T-F0tBpxHEKpBTf/view?usp=sharing

3) Verify your installation

You can test the code by running the tutorial below.

3 Using Pinchpoint Mapper

3.1 Input data requirements

Inputs to Pinchpoint Mapper include 1) the same inputs used in Linkage Pathways (a core area polygon layer and a resistance raster) and 2) rasters generated from a completed Linkage Pathways run.

3.2 Running the toolbox



Note: ArcGIS can be finicky about file locks. If you get schema lock or permission errors, you may need to close any active ArcGIS processes and start fresh without any output files displayed.



*Note: Several users have reported that they experience fewer ArcGIS Desktop errors when running from ArcCatalog. **We therefore suggest you run from ArcCatalog if you are having problems with ArcMap.***

Click on the *Pinchpoint Mapper* tool, which is located in the *Additional Tools* toolset in the *Linkage Mapper* toolbox. The following dialog should appear.

Figure 2. Pinchpoint Mapper dialog in ArcGIS Desktop.

A. Input data

- a. **Project directory:** Use the same project directory used for the Linkage Pathways run.
- b. **Core area feature class:** Use the same core area file you used to create corridors using Linkage Pathways.

- c. **Core area field name:** Use the same core area field name you used to create corridors using Linkage Pathways.
- d. **Resistance raster:** Use the same resistance raster used to create corridors using Linkage Pathways.

B. Options

- a. **CWD cutoff distance:** This is how 'wide' corridors should be in cost-weighted distance. See the description of *Linkage Mapping Cutoff* in Chapter 2 of WHCWG (2010). Corridors will be 'cookie-cut' using this cutoff value.
- b. **Square resistance values:** Some practitioners use higher resistance values for Circuitscape than for least-cost corridor analyses. Squaring values is an easy way to accomplish this (though there is no empirical support either way for doing so).



Note: for processing efficiency in Circuitscape, we recommend that the highest resistance values do not exceed 10,000 times the lowest values.

- c. **Calculate adjacent pair pinch points using Circuitscape:** Run current through individual corridors connecting adjacent core areas as mapped by Linkage Pathways. Current will be limited to areas below the CWD cutoff distance in each corridor. Current values will be mosaicked across all corridors.
- d. **Calculate raster centrality using Circuitscape:** Runs current between all core areas in network. The resistance map will be 'cookie-cut' to the corridor map produced by Linkage Pathways, and will only include areas below the CWD cutoff distance.
- e. **Circuitscape mode for raster centrality calculations:** Pairwise mode will run current between all pairs of core areas. All-to-one mode will tie one core area to ground and inject current into the remaining cores, iterating across all cores. Current will then flow through these areas between all connected core areas. Results for each pair of core areas (pairwise mode) or each core area (all-to-one mode) will be summed in the output current map. Both outputs show areas that have high current flow centrality, indicating their importance for keeping the entire network connected (see McRae et al. 2008, Carroll et al. 2012). Pairwise mode provides a more intuitive centrality measure, but all-to-one mode is faster if you have many core areas. See Circuitscape User Guide for more details on these modes.

3.3 What Pinchpoint Mapper does

Pinchpoint Mapper calls Circuitscape in pairwise and/or all-to one mode. Pairwise mode will be applied for the adjacent pair pinch points option and for raster centrality calculations if pairwise mode is chosen. All-to-one mode will be applied for raster centrality calculations if all-to-one mode is chosen.

Outputs rasters will be written to `pinchpoints.gdb` in your output directory. If adjacent pair pinch points are run, `stick` and `LCP` maps in `link_maps.gdb` will be updated with effective resistance values (see McRae and Shah 2009) and `cwd-to-effective-resistance` ratios. Output rasters are named using the following convention:

`<Project directory name>_current_<mode>_<cutoff value>_<nodata option>`

Mode indicates the run setting, and includes `adjacentPairs`, `allPairs`, and `allToOne`. *Cutoff value* is the CWD cutoff value used as the corridor width. *Nodata option* indicates whether core areas

have been set to NoData in the output raster (which can help with color ramping your current maps). For raster centrality analyses, maps with and without the NoData option are automatically produced.

4 Pinchpoint Mapper tutorial

After running the Linkage Pathways tutorial, you can analyze pinch points in your output corridors. Open up LM_demo_results.mxd, and run Pinchpoint Mapper using the following settings (substitute the path to your own demo directory). I recommend experimenting with different CWD cutoff distance values to get a feel for how they affect results, and trying the pairwise setting for raster centrality calculations.

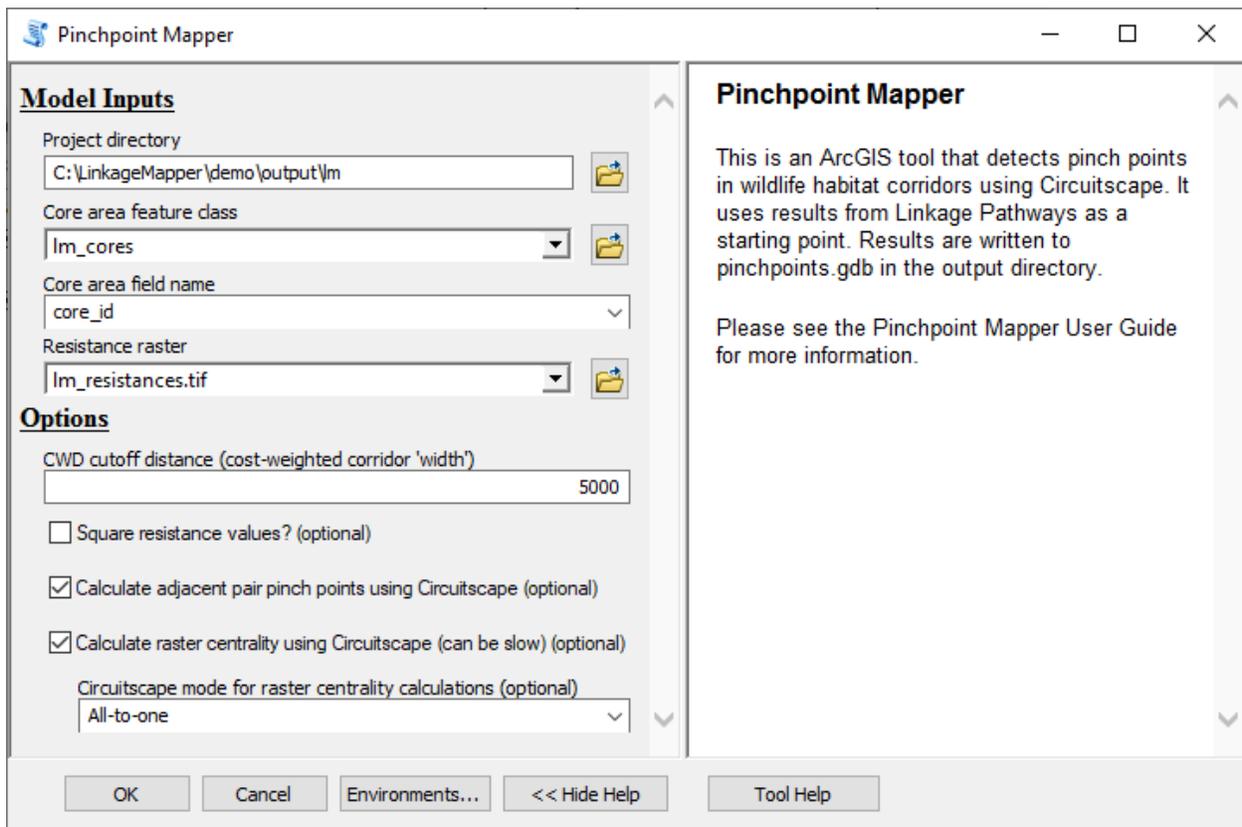


Figure 3. Tutorial settings. If applicable, substitute the input for the *Project Directory* parameter with the path to your demo project directory.

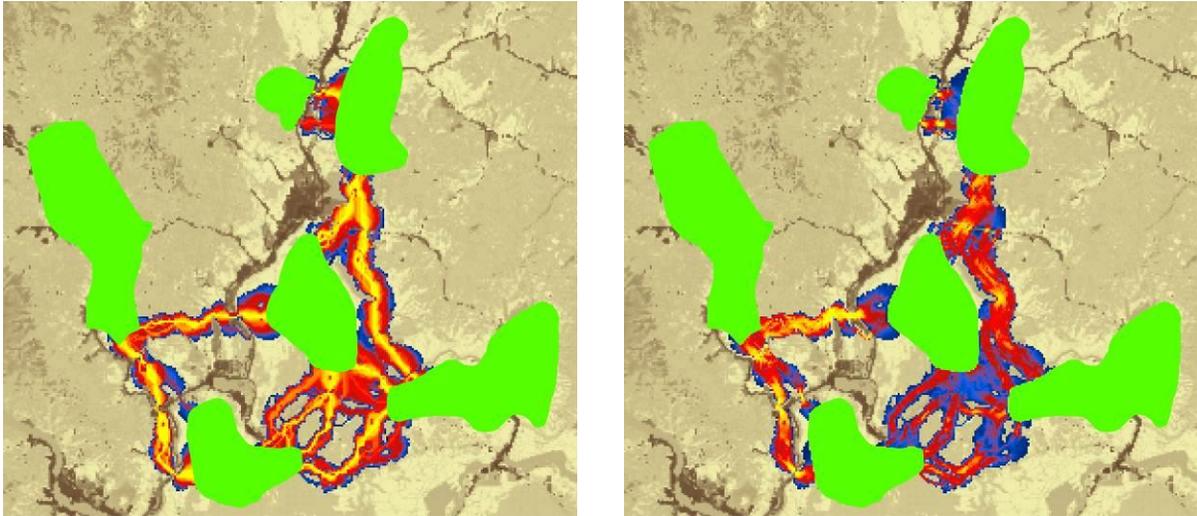


Figure 4. Above left are corridors from Linkage Pathways tutorial. Corridors have been clipped to a 5 km cost-weighted 'width' cutoff using **Clip Corridors to Cutoff Width** tool in the Linkage Mapper Utilities toolset. Right: adjacent pair current maps using 5 km CWD cutoff distance. Areas with high current values (yellow) indicate pinch points within individual corridors. Current densities were symbolized in ArcMap using a quantile classification.

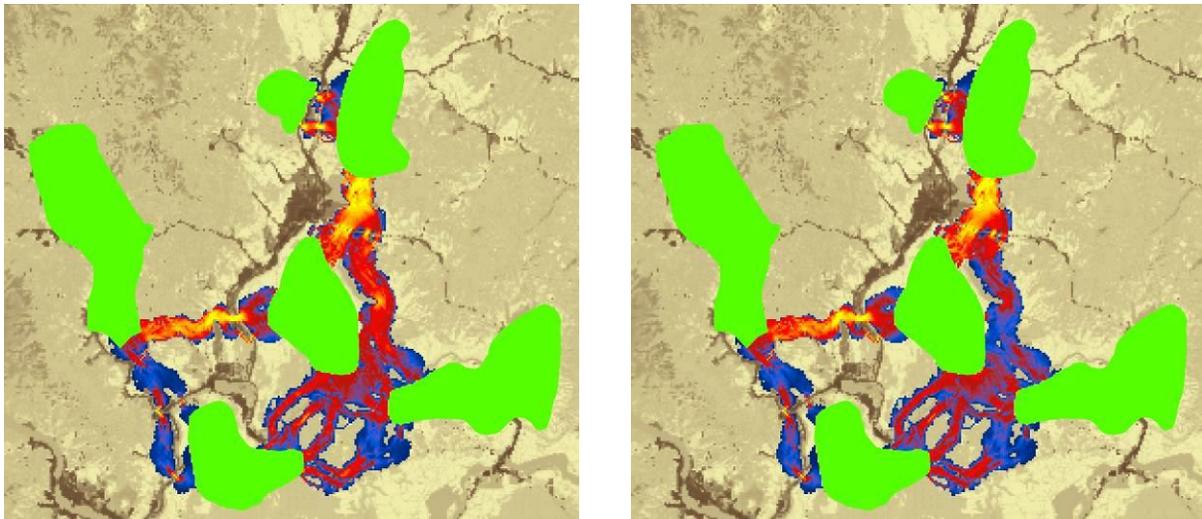


Figure 5. Above left: results from raster centrality analyses using pairwise mode with 5 km CWD cutoff. This shows areas that have high current flow centrality, indicating their importance for keeping the entire network connected (as opposed to keeping a single core area pair connected as in Fig. 4; see McRae et al. 2008, Carroll et al. 2012). Right: raster centrality results using all-to-one mode. Results bear a strong resemblance to pairwise results, but all-to-one can be much faster when there are large numbers of core areas.

5 Community

Please join the Linkage Mapper Google Groups forum at <https://groups.google.com/g/linkage-mapper> to get updates, report bugs, and suggest enhancements. Please also visit the project website at <https://circuitscape.org/linkagemapper/>.

To contribute to the development of Linkage Mapper explore our code repository on GitHub: <https://github.com/linkagescape/linkage-mapper>.

6 Literature cited

- Carroll, C., B.H. McRae, and A. Brookes. 2012. Use of linkage mapping and centrality analysis across habitat gradients to conserve connectivity of gray wolf populations in western North America. *Conservation Biology* 26(1):78-87.
- McRae, B.H., B.G. Dickson, T.H. Keitt, and V.B. Shah. 2008. Using circuit theory to model connectivity in ecology, evolution, and conservation. *Ecology* 10: 2712-2724.
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