The Smart Infrastructure Planner Toolkit User Guide

The main objective of the Smart Infrastructure Planner (SIP) Toolkit is to identify change in habitat suitability for a focal species given planned infrastructure or land use and to quantify the resulting changes in the landscape.

Introduction to Expert-based Habitat Modeling

This toolbox is based in expert-based habitat modeling theory. In this, experts of the focal species weight environmental variables on a relative scale of 1 – 100, 1 being the least influential in determining the focal species' presence and 100 being the most influential in determining focal species presence. These weights of each environmental variable should add to 100. Then, within each environmental variable, different attributes or categories are alternatively weighted on a scale of 0-10. Here, a 10 represents the best suitable habitat or attribute of the environmental variable for the focal species and a 0 or 1 represents the worst habitat. This is a relative scale and each category within the environmental variable should have a weight. These do not need to add to 100 and a weight may be used multiple times.

For example, if it is determined by experts that land cover, roads and settlements all influence tiger presence and land cover is the primary factor in determining tiger presence and roads and settlements have the same influence on tiger presence, experts may arrive at the following weights:

Environmental Variable	Weight
Land Cover	50
Roads	25
Settlements	25

Alternatively, if roads have a slightly larger influence on tigers than settlements, experts may arrive at the following weights:

Environmental Variable	Weight
Land Cover	50
Roads	30
Settlements	20

If experts decide that deciduous forest is the most important and best tiger habitat, evergreen forest is moderate habitat, grassland is bad habitat and developed land is completely inhabitable for tigers, experts may arrive at the following within-variable scores:

Land Cover Class	Score
Deciduous Forest	10
Evergreen Forest	8
Grasslands	3
Developed/Urban Area	0

Often, the distance from roads and settlements is used as a proxy for estimating the diminishing effects these variables have on wildlife instead of the point or line location of the city or road itself. If this is the case, you should score the distance classes which influence your focal species presence.

For example, if tigers prefer to be greater than 10 km from a major road, 5-10 km is moderate habitat and 0-5 km is poor habitat the scoring may be the following:

Distance Class	Score
>10 km	10
5 – 10 km	5
< 5km	1

Each class or category within each environmental dataset should have a score.

After experts weight the environmental variables and score the attribute or categories within these variables, they are combined using a weighted sum. The output is a suitability map of a 0 - 1000 scale. A score of 1000 represents the absolute best habitat for your focal species and a score of 0 represents the worst habitat for the species.

Experts should agree upon a threshold of ‘good’ habitat, ‘moderate’ habitat and ‘poor’ habitat. For example, if the focal species only maintains sustainable populations in extremely good habitat and the object of your study is to identify areas where these populations may be, experts may want to use a suitability score of 800 as ‘good’ habitat, scores between 500 and 800 as ‘moderate’ habitat and scores <500 as ‘poor’ habitat. These scores will depend on your focal species and the purpose of your study.

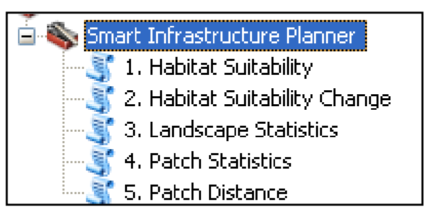
Experts must also determine what a ‘core’ area is. A ‘core’ area may be defined many different ways. If you aim to identify areas in the landscape that can maintain a certain number of breeding individuals who will disperse to populate surrounding habitat, you should select an area large enough and of high enough quality to contain the home range for this number of individuals. For example, to contain 25 breeding female tigers in the Lower Mekong Forests of Cambodia, Laos and Vietnam, it is thought 1,750km^2 is needed. It follows then, that a core area must be at least 1,750km^2 and must be good quality habitat.

Applying the Tool

The Smart Infrastructure Planner is both an analytical process and a toolset that helps guide this process. Processes should be applied sequentially, with inputs and outputs examined at each step of the process. The process should be considered iterative, and portions can be rerun when new data or information are acquired. The strength of the SIP is that it is automated, so that it is easy to repeat analyses with slight modifications. The steps to undertaking an analysis with the SIP are as follows:

1. Agree on the focal species or ecosystem of interest
2. Gather information, including habitat use, and spatial data on observations and environment (land cover, cities, roads, planned infrastructure, etc.) and identify experts
3. Experts rank environmental drivers of the species and run model
4. Run modules of Smart Infrastructure Planner

    a. Habitat Suitability
    b. Habitat Suitability Change
    c. Landscape Statistics
    d. Patch Statistics
    e. Patch Distance



1. Agree on Focal Species and/or Ecosystem

   The SIP is a tool that focuses on one species, suite of species or ecosystem. The results of the tool reflect the landscape change with respect to the focal species or ecosystem. Selection of a focal species and ecosystem will depend on the purpose of the study.

2. Gather Information and Identify Experts

   Environmental variables that influence the presence of the focal species should be identified for inclusion in the tool. It has been recommended that no more than five non-correlated environmental variables (Beier *et al*. 2008) are used in habitat modeling. These data should then be acquired in spatial format (Table 1). For each ecosystem or species, experts should be identified and surveyed to determine the environmental variables to include in the model and their weights. Using multiple, long-term, local experts that consult literature can increase the accuracy of the model output (Clevenger *et al*. 2002, Hurley, Rapaport & Johnson 2009).

3. Experts Rank Environmental Drivers

   Experts should weight and score the environmental variables and their attributes as described above. These weights and attribute scores should be entered into the Habitat Suitability tool, the first tool in the SIP toolbox. Required environmental variables for the tool include, towns, cities, major roads, minor roads and land cover. Optional variables include mines, slope, protected areas, rivers, lakes, prey occupancy, poacher locations and villages. For instructions on how to incorporate dams, see Appendix 1.

4. Run Modules of Smart Infrastructure Planner

   There are five tools within the Smart Infrastructure Planner (SIP). The first tool is the most complex and takes the longest to run. This is called Habitat Suitability. If you have occurrence data of your focal species, you may substitute MaxEnt for this tool (see Appendix 2). The second tool, Habitat Suitability Change identifies the change in habitat suitability between two different scenarios. Landscape Statistics, the third tool, calculates the area of different habitat qualities. The Patch Statistics tool calculates statistics for all of the habitat patches (core areas and non-core areas) within your focal landscape. The fifth and final tool in the toolkit is called Patch Distance tool and determines whether the landscape is functionally connected if your focal species has the capacity to disperse between habitat patches. All tools should be run twice; once for the current scenario and once for the future scenario, except the Habitat Suitability Change tool.

   a. *Habitat Suitability* The Habitat Suitability tool requires input of the environmental variables, weights and scores and a habitat quality threshold as described above. All of the current data should be included with the future data when running the future scenario analysis.

   b. *Habitat Suitability Change* To determine how the landscape has changed from one time step to the next, the user can use the outputs from the Habitat Suitability tool to obtain a map of habitat change using the Habitat Suitability Change tool.

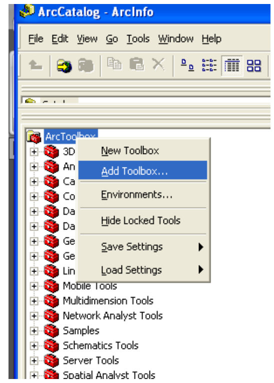
   c. *Landscape Statistics* The Landscape Statistics tool takes the output from the Habitat Suitability tool and breaks the entire study area into ‘good’, ‘moderate’ and ‘poor’ habitat based on user defined thresholds. The ‘good’ habitat threshold used in the Habitat Suitability tool should also be used here to define ‘good’ habitat.

d. *Patch Statistics* To further assess how specific habitat patches are projected to change with planned infrastructure, the Patch Statistics tool may be used. The inputs to this tool include the patch layer (output from the first tool) and a definition of 'core' area with regard to the focal species. A core area may be defined many different ways. If the aim is to identify areas in the landscape that can maintain a certain number of breeding individuals that will disperse to populate surrounding habitat, the user should select an area large enough to contain the home ranges for this number of individuals. For example, experts estimate that 1,750 km^2 is required to support 25 breeding female tigers in the Lower Mekong Forests of Cambodia, Laos and Vietnam. The output of the Patch Statistics tool is a summary table describing the distribution of core patches vs. non-core patches along with their total area, mean area, mean perimeter and mean perimeter/area ratio. This tool also modifies the attribute table of the patch input layer by labeling all of the patches as 'core' patches or 'non-core' patches. The modified shapefile will also include area, perimeter and perimeter/area ratio for each patch.

e. *Patch Distance* Finally, to determine how connectivity between habitat patches change from one scenario to another, the Patch Distance tool should be used. Inputs for this tool include the patch layer output from the Habitat Suitability tool and modified in the Patch Statistics tool, (where patch area, perimeter and perimeter/area ratio are calculated) and a maximum dispersal distance, or the distance the focal species will travel between suitable habitat patches. The user will receive an output map depicting the habitat patches (core and non-core) that are connected based on the maximum dispersal distance. For each core, the closest neighbor core is identified and as an optional output, for each non-core patch, the closest core patch is identified. These distances are also provided as output in a table. To calculate the cost distance between patches, see Appendix 3.

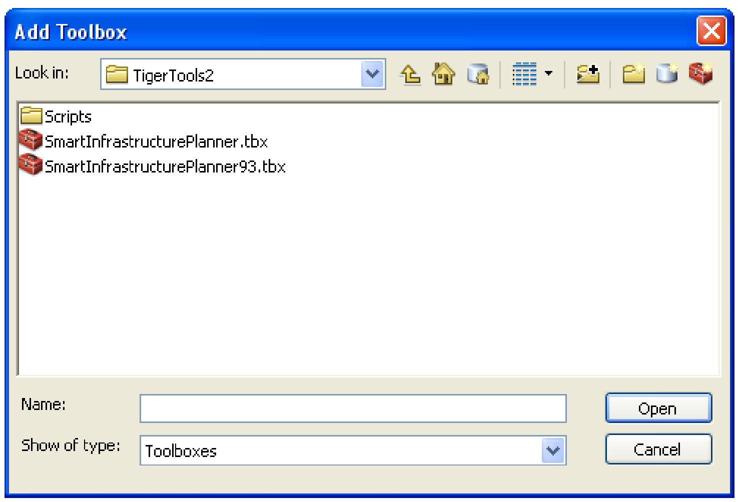
PART 1. Adding the toolbox to ArcMap or ArcCatalog:

1. Right click on the ArcToolbox and select 'Add Toolbox'.



2. In the dialog box that appears, navigate to the Smart Infrastructure Planner folder. Click on the toolbox that corresponds to your version of Arc (use SmartInfrastructurePlanner93.tbx if you have Arc 9.3.x and SmartInfrastructurePlanner.tbx if you have Arc10) and select 'Open'.

   There is no recommended folder structure for using this toolbox. You may find it easier to move all of your inputs into one folder and create a folder specifically for outputs before running the SIP.



The SIP toolbox should now be added to your ArcToolbox.

Important Information for Running the SIP:

- **System requirements: ArcGIS 9.3/Python 2.5 or ArcGIS 10/Python 2.6, ArcInfo license and the Spatial Analyst extension, installed and activated**
- **Pathnames must not have any spaces, must be less than 100 characters long (including filenames), must not have nested double names (C:\Workspace\Workspace, for example), must not have special characters such as dashes or semi-colons, and must not have a number as the first character in the file name.**
- **All input datasets must be clipped to your study area**
- **All data must be in a planar coordinate system(not degrees latitude and longitude)**
- **Intermediate data from previous runs must not be open in any Arc windows**

If these requirements are not met, the SIP will not run properly, if at all.

PART 2. Running the Habitat Suitability Tool

1. Double click on the script tool Habitat Suitability. A dialog box will appear. There are many inputs for this tool, but the tool *requires* only three datasets to run successfully: Land cover, Settlements and Roads.

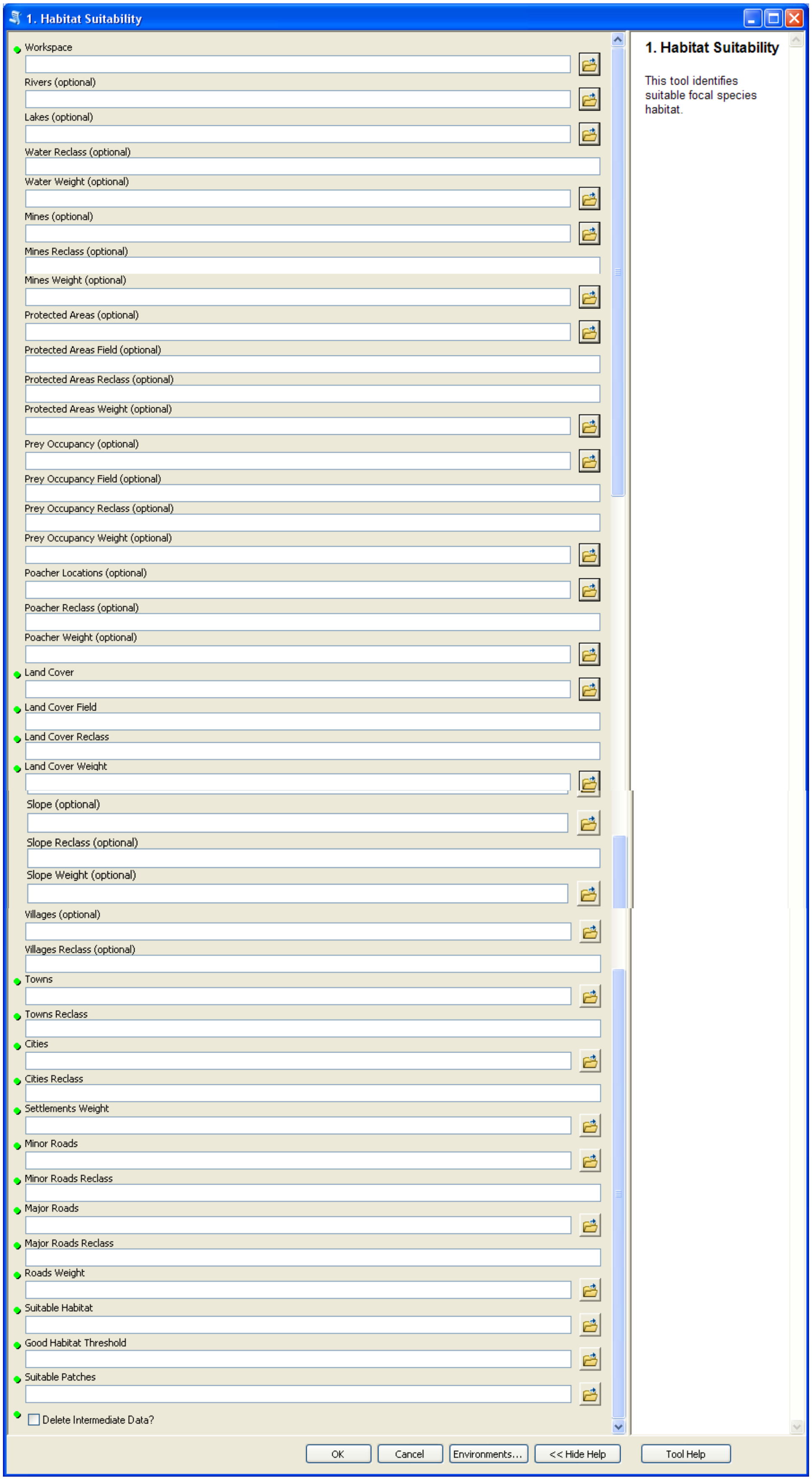
   Other datasets that may be used are Lakes, or a polygon water layer, Rivers, or a line water layer, Mines, Protected Areas in raster format, Prey Occupancy in raster format, Poacher Locations and Villages. You may choose to input any or none of these optional datasets depending on the landscape you are working in, the available data and the sensitivity of a focal species or habitat type to these environmental variables. For instructions on how to incorporate dams, see Appendix 1.

   If you should choose to include a measure of prey occupancy in the Habitat Suitability Model, you are probably aware that number of sites and surveys, survey design and occupancy may all affect the accuracy of this data. Please use this data with caution.

   *** It is recommended that you select only the most important environmental variables to include here. Including more than five and including highly correlated variables can result in misleading and inaccurate results.*

   *See: Beier, P., Majka, D.R. and Spender, W.D. 2008. Forks in the roads: choices and procedures for designing wildland linkages. Conservation Biology, 22(4): 836-851 ***

   This model may take up to an hour to run.


1. Habitat Suitability
Workspace
Rivers (optional)
Lakes (optional)
Water Reclass (optional)
Water Weight (optional)
Mines (optional)
Mines Reclass (optional)
Mines Weight (optional)
Protected Areas (optional)
Protected Areas Field (optional)
Protected Areas Reclass (optional)
Protected Areas Weight (optional)
Prey Occupancy (optional)
Prey Occupancy Field (optional)
Prey Occupancy Reclass (optional)
Prey Occupancy Weight (optional)
Poacher Locations (optional)
Poacher Reclass (optional)
Poacher Weight (optional)
Land Cover
Land Cover Field
Land Cover Reclass
Land Cover Weight
Slope (optional)
Slope Reclass (optional)
Slope Weight (optional)
Villages (optional)
Villages Reclass (optional)
Towns
Towns Reclass
Cities
Cities Reclass
Settlements Weight
Minor Roads
Minor Roads Reclass
Major Roads
Major Roads Reclass
Roads Weight
Suitable Habitat
Good Habitat Threshold
Suitable Patches
Delete Intermediate Data?
OK
Cancel
Environments...
<< Hide Help
Tool Help
1. Habitat Suitability
This tool identifies suitable focal species habitat.

2. Select the workspace in which you want to save your outputs. All of the outputs and intermediate data sets will be saved here. The folder you select should have no spaces in the pathname.

******If you are not including water, mines, protected areas, prey occupancy or poacher location layers, skip to Step 20******

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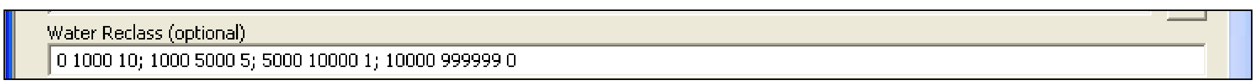
3. *(Optional; you may select just rivers, just lakes or neither)* Select the river and lakes shapefiles you wish to include by clicking on the folder next to their boxes.

4. Type in the bounds of each distance class with just a space between them (For example, for 0m-1000m type in "0 1000"). After the high end of the distance class, type a space, then the score to be assigned to that distance class. This should be immediately followed by a semi-colon (;). Repeat this syntax for all of the classes within the environmental variable. The total distance class reclassification should look something like: 0 1000 10;

   Rivers and lakes will be combined in the model, so the scores for distance classes are for both rivers and lakes. If you are using a projection in meters (UTM), you must define your distance classes in meters.



5. Type in the weight for the total water layer.

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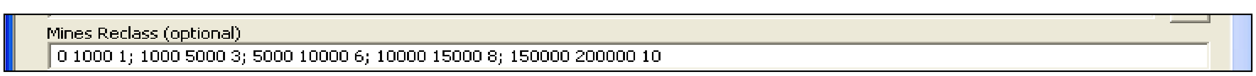
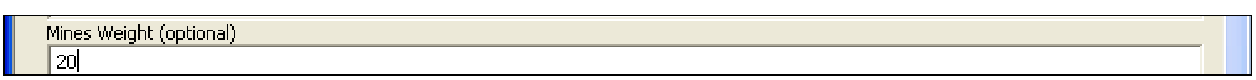
6. (*Optional; you do not need to input a mines layer*). Select the mines layer you wish to include by clicking on the folder next to the 'Mines' box and adding it.

7. Type in the scores for the distance classes to be defined. If you are using a projection in meters (UTM etc.), you must define your distance classes in meters.



8. Type in the weight for the mines layer.



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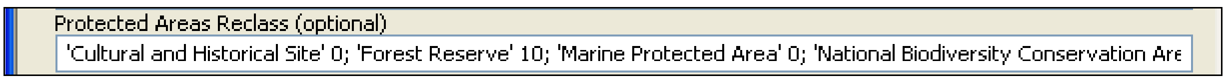
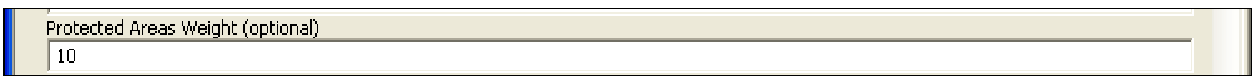
9. (*Optional; you do not need to input a protected areas layer*). Select the protected areas layer you wish to include by clicking on the folder next to the 'Protected Areas' box and adding it. This layer should be in raster format.

10. Type in the field, or column heading, from the Protected Areas attribute table that contains the protected areas designation. *This needs to match the name of the attribute exactly*.

11. Type in the scores for each protected area designation. Each protected area designation you type in must exactly match the attribute table (spellings and spacing between words must match). Additionally, the each designation type must be enclosed in single quotations (if you use the 'Value' field for the reclassification, do not enclose the Values in single quotations).



12. In the box labeled 'Protected Areas Weight', type in the weight for the protected areas layer.



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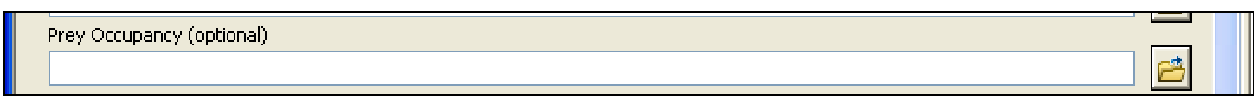
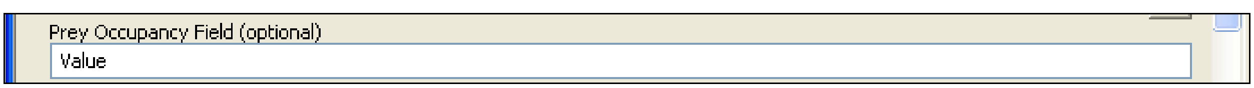
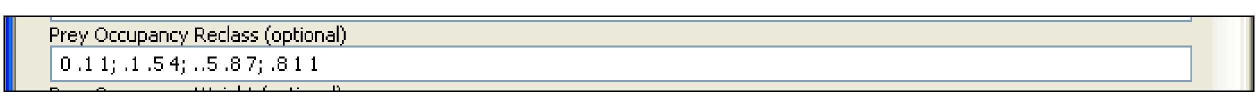
13. (*Optional; you do not need to input a prey occupancy layer*) By clicking on the folder next to the box labeled 'Prey Occupancy', navigate to the raster layer describing prey occupancing for your study area and click 'Open'.



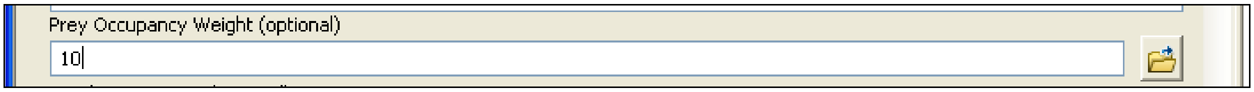
14. In the next box, 'Prey Occupancy Field', type in the column heading from the prey occupancy attribute table that contains the information about prey occupancy. *What you type in here needs to match the name of the attribute table column heading exactly.*



15. Type in the reclassification scheme in the following box. This should be the prey occupancy categories within the attribute you designated in the 'Prey Occupancy Field' box, followed by a space and the category's new score, separated by a semicolon.



16. Finally, in the 'Prey Occupancy Weight' box, type in the relative weight of the Prey Occupancy layer. The weights of all environmental variables you include in the model must add to 100.



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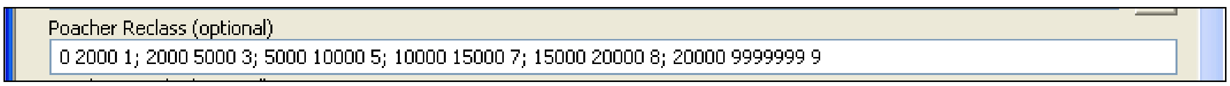
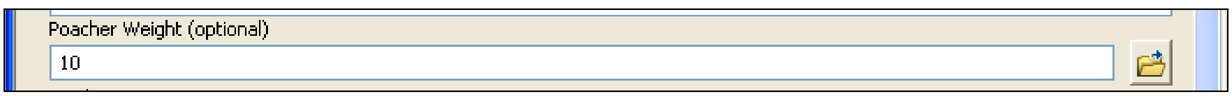
17. (*Optional; you do not need to input a poacher location layer*) Click on the folder next to the 'Poacher Location' box and navigate to the shapefile (point, line or polygon) of poacher sightings, known poaching locations, poacher access points, etc. Click 'Open' to add the shapefile to the tool.

18. Type in the scores for the distance classes from poacher locations to be defined. If you are using a projection in meters (UTM etc.), you must define your distance classes in meters.



19. In the 'Poacher Weight' box, type in the relative importance of this layer compared to the other environmental variables. The sum of all of the weights must be 100.



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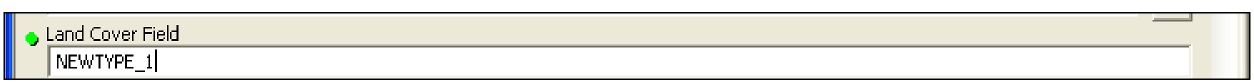
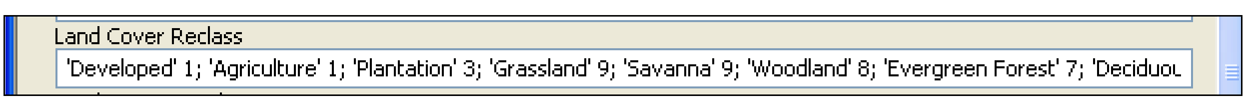
20. By clicking on the folder next to the box labeled 'Land Cover', navigate to the raster land cover dataset for your study area and click 'Open'.

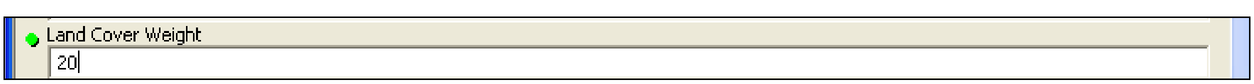
21. In the next box, 'Land Cover Field', type in the field (column heading) from the land cover attribute table that contains the land cover class you will use. *This needs to match the name of the attribute exactly*.



22. Type in the scores in the following box. This should be the land cover classes within the attribute you designated in the 'Land Cover Field' box, followed by a space and the land cover type score, separated by a semicolon. The name of the land cover type should be enclosed in single quotation marks. If you use the 'Value' field for the reclassification, do not put single quotation marks around the value. The total reclassification should look something like: 'Evergreen' 10; or: 1 10;

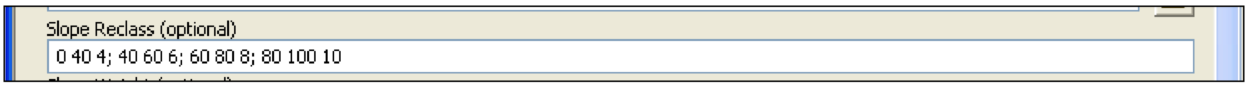


23. To complete the land cover section, type in the weight of the land cover layer in the box labeled 'Land Cover Weight'.

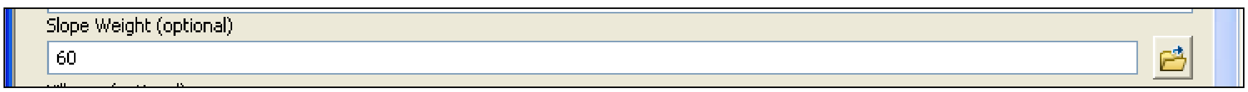


24. (*Optional; you do not need to input a slope layer*). Click on the folder next to the 'Slope' box, and navigate to your slope raster dataset. This should be a layer created from a raster elevation dataset. You may use either degrees or percent to represent the slope of the landscape.

25. In the next box, type in the scores for each category of slope. As with the distance classifications used for the mines, roads and cities layers, it is up to you and the species experts to determine what thresholds of slope influence the focal species.



26. To complete this section, type in the weight of the slope layer in the box labeled 'Slope Weight'.



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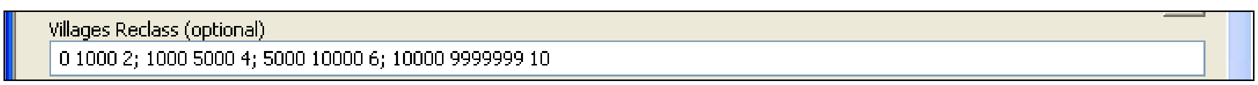
27. (*Optional; you do not need to input a villages layer*) Click on the folder next to the 'Villages' box, and navigate to your villages shapefile. Click 'Open' to add it to the tool.

28. In the next box, type in the distance classes from villages that affect the presence of your focal species and their category scores.



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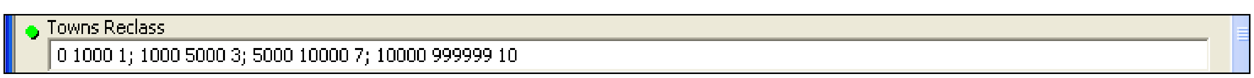
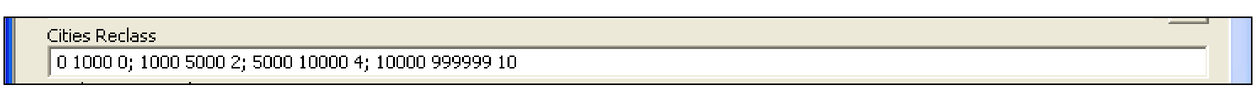
29. Select the towns shapefile you wish to include in the next box.

30. In the box labeled 'Towns Reclass', type in the distance classes from towns that affect the presence of your focal species or habitat type and their scores.

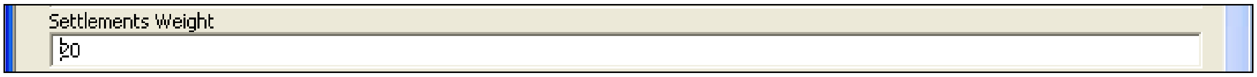


31. Select the cities shapefile you wish to include in the box labeled 'Cities'.

32. In the 'Cities Reclass' box, type in the distance classes from cities and the scores.



33. Next enter the weight of the settlements in the ‘Settlements Weight’ box. The towns and cities will be combined in the model, so this weight should reflect the overall importance in settlements in influencing the presence of the focal species.

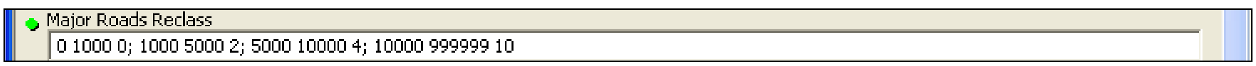


34. Navigate to your minor roads dataset by clicking on the folder next to the ‘Minor Roads’ box. Add the dataset.

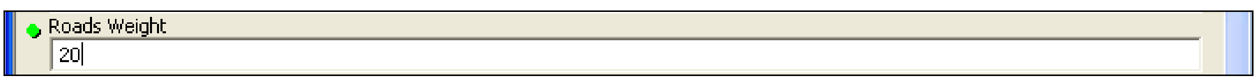
35. In the ‘Minor Roads Reclass’ box, define the distance classes that affect focal species presence and their scores.

36. Next, select the major roads dataset you wish to include.

37. Define the distance classes that affect the focal species presence and their scores in the ‘Major Roads Reclass’ box.

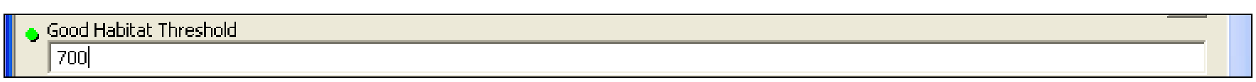


38. Enter the weight of the roads in the ‘Roads Weight’ box. The minor and major roads will be combined in the model, so this weight should reflect the overall importance in roads in influencing the presence of the focal species.



39. In the ‘Suitable Habitat’ box, type what you would like the final output layer to be called. This output will be in raster form. There is a character limit of 13 for raster files. No spaces or special characters except underscores (_) are allowed. If you do not select a folder by clicking on the folder button, the output will automatically be placed in your previously chosen workspace.

40. In the ‘Good Habitat Threshold’ box, type in the expert-defined value which is considered ‘good habitat’. (See Introduction for a detailed explanation)



41. In the last box, ‘Suitable Patches’, type what you would like this output to be called. This layer identifies contiguous ‘good’ habitat patches and is in shapefile format.

42. Finally, if you want to delete all of the intermediate data that will be created from running the tool, check the ‘Delete intermediate data?’ box. If you want to retain the intermediates for error checking, for example, do not check the box. Intermediates will be stored in your designated workspace.

43. If all of the required (green dot) fields and the optional fields of your choosing are filled in, then click 'OK'. Outputs include a shapefile of habitat patches and a raster layer of habitat suitability on a scale of 0-1000, where 1000 is perfectly suitable habitat and 0 is completely unsuitable habitat.

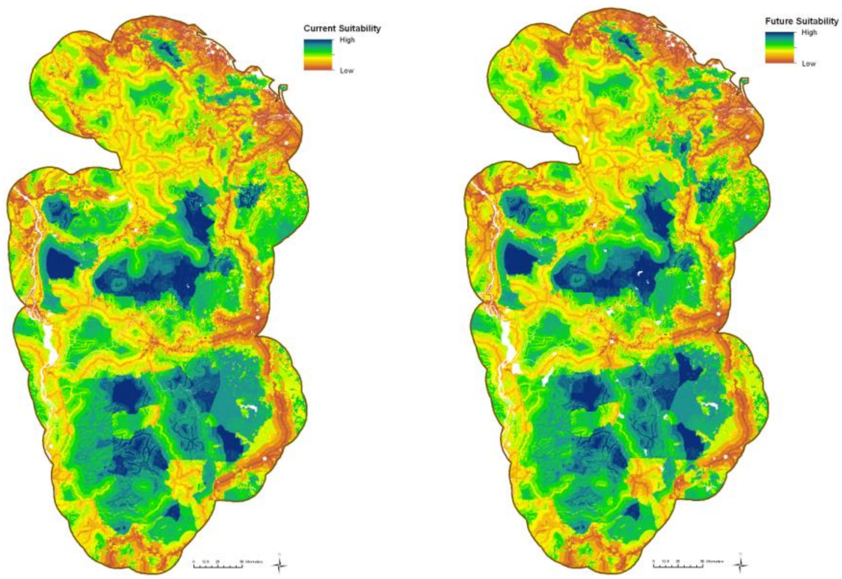


Figure 1. Example output from the Habitat Suitability tool. Run the tool twice to obtain current suitability (left) and future suitability (right).

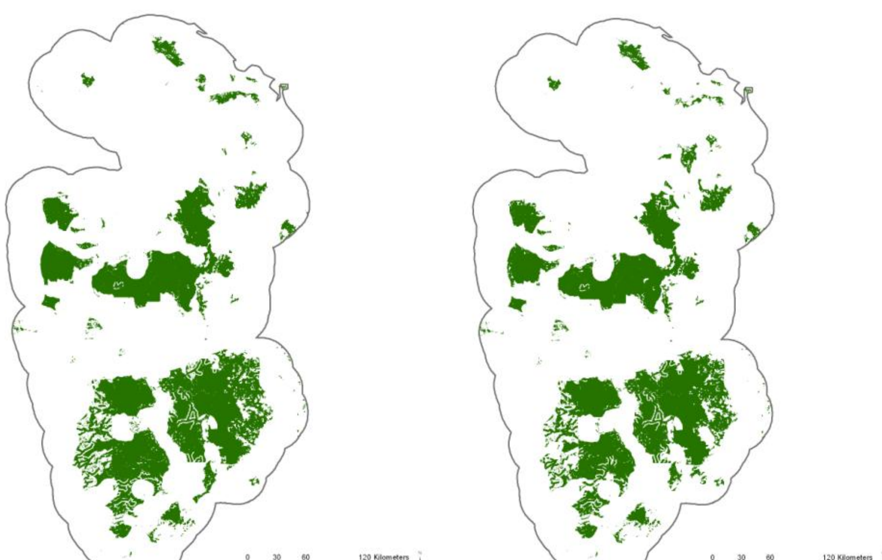
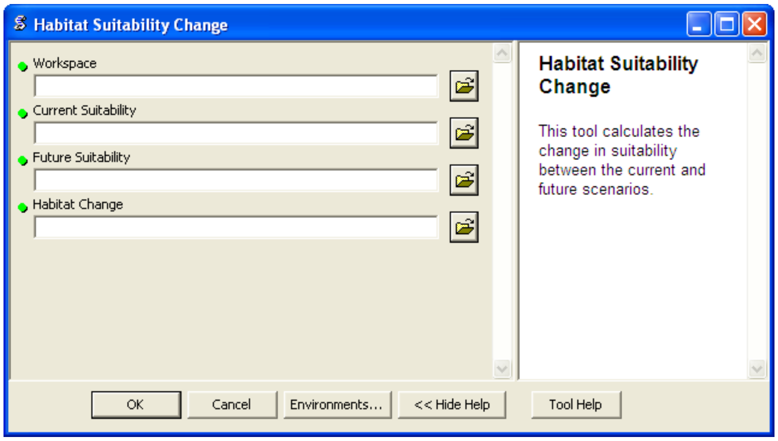


Figure 2. Example out from the Habitat Suitability tool of habitat patches. Core and non-core areas have not yet been identified.

PART 3. Running the Habitat Suitability Change Tool

1. Double click on the Habitat Suitability Change tool. This tool requires two input suitability layers resulting from the Habitat Suitability tool and provides one output of suitability change between the current scenario and the future scenario. This tool only takes a few minutes to run.



2. In the ‘Workspace’ box, click the folder button and navigate to the workspace you would like your outputs to go to.

3. In the next box, navigate to your Current Suitability layer. This is the current scenario output from the Habitat Suitability tool.

4. Navigate to the Future Suitability layer in the next box by clicking on the folder button. Click ‘Open’.

5. Finally, type in what you would like the output change raster dataset called in the ‘Habitat Change’ box. The output of this layer is a raster depicting the change in habitat from the current to the future scenario. High values represent a decrease in suitability and low values represent an increase in suitability.

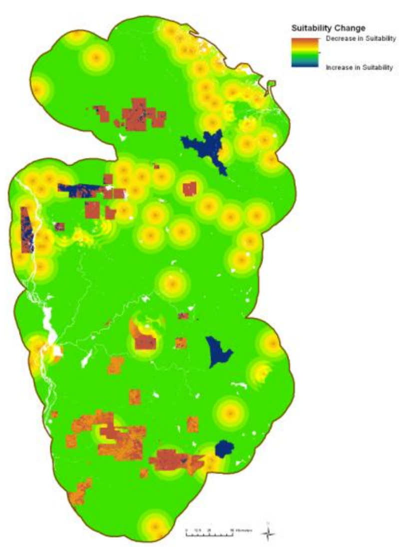
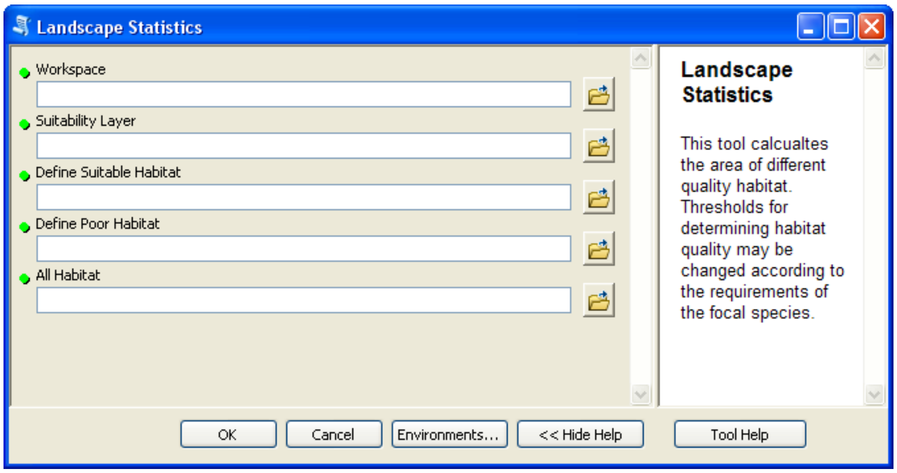


Figure 3. Sample output from Habitat Suitability Change. High values (red) represent decreases in suitability and low values (blue) represent increases in habitat suitability.

PART 4. Running the Landscape Statistics Tool

1. Double click the Landscape Statistics tool. This tool requires one input layer, the raster habitat suitability layer, and provides one output raster dataset.

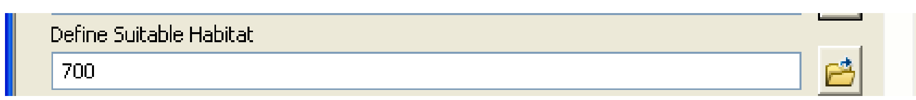
   This tool will not run if there are spaces in the suitability layer pathname



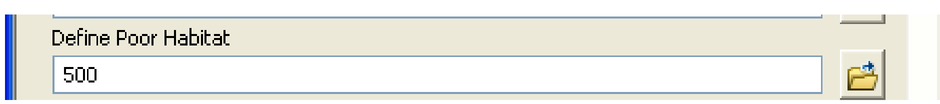
2. In the first box, select the workspace in which you want to save your outputs.

3. In the 'Suitability Layer' box, click on the folder button and navigate to the raster output layer from the Habitat Suitability tool (if you are running this tool for the current scenario, use the current Habitat Suitability output, and if you're running this for the future scenario, use the future Habitat Suitability output). Click 'Open'.

4. In the next box, you must define 'suitable' habitat. Pick a Suitability threshold (a value 0 – 1000), above which is 'suitable' habitat for your focal species. You may use the same threshold used in the 'Good Habitat Threshold' box in the Habitat Suitability tool.



5. In the next box, you must define 'poor' habitat for the focal species. Pick a Suitability threshold (a value 0 – 1000), below which is 'poor' habitat where the focal species may be unlikely to be found.



6. The final box, 'All Habitat', provides a space to type in the name of the output raster layer of all habitat types ('suitable', 'moderate' and 'poor'). The attribute table of this raster layer contains the area of all habitat types.

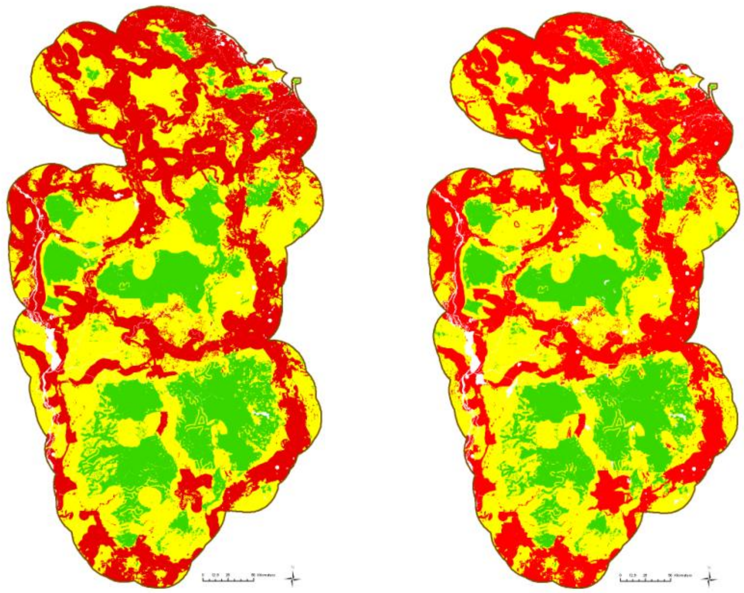


Figure 4. Sample out from the Landscape Statistics tool. Landscape quality categories, 'good' (green), 'moderate' (yellow) and 'poor' habitat (red) for the current (left) and future (right) scenarios. The area of each category is calculated and displayed in the attribute table.

Attributes of landstats

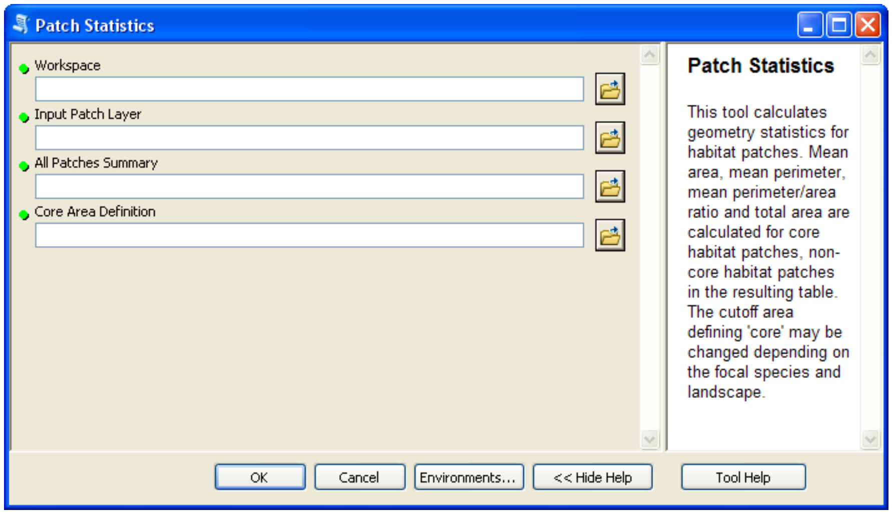
Rowid	VALUE *	COUNT	TYPE	AREA
0	1	28327758	Good	25494.982
1	2	62573080	Moderate	56315.773
2	3	54061352	Poor	48655.219

Record: 1 Show: All Selected

Figure 5. Example attribute table from the Landscape Statistics tool. Area is calculated in square kilometers.

PART 5. Running the Patch Statistics Tool

1. Double click the Patch Statistics tool. This tool requires one input layer, provides one summary statistics table and modifies the input layer.

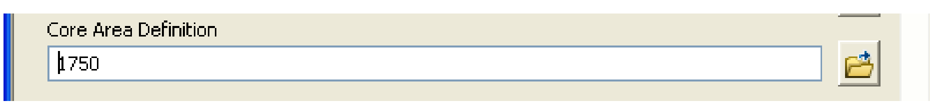


2. In the ‘Workspace’ box, navigate to the folder in which you want to save the outputs from this tool.

3. The ‘Input Patch Layer’ is the habitat patch layer resulting from the Habitat Suitability tool. Select this layer using the folder button next to the ‘Input Patch Layer’ box.

4. The ‘All Patches Summary’ box refers to a table that is an output from this tool. This table will contain summary statistics for all of the patches in the input patch layer. To view the table in ArcMap after the tool runs, type in the desired table name with a ‘.dbf’ extension. The table name should not contain any spaces or special characters other than underscores (_).

5. In the next box, ‘Core Area Definition’, you must define the area of a ‘core’ habitat. This will depend on your focal species and its habitat. If habitat patches greater than 500 km^2 may be considered ‘core’ type in: 500. (Area must be in square kilometers)



6. Click OK. This tool only takes a few minutes to run. The area, perimeter and area/perimeter ratio for all the patches will also be added to the attribute table of the input patch layer.

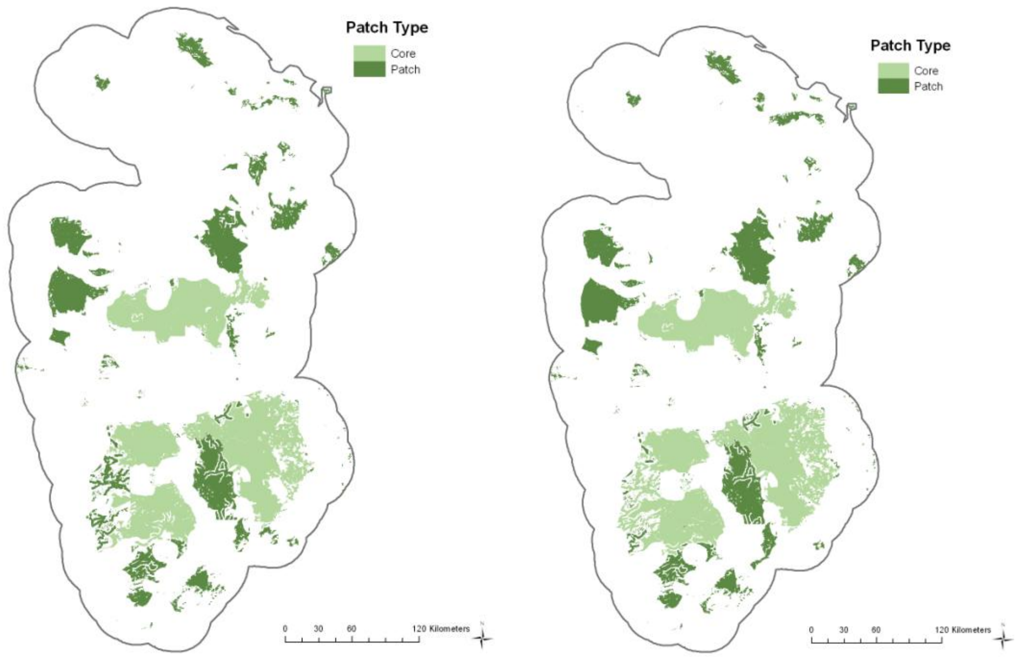


Figure 6. Example output from Patch Statistics tool. In the patch layer output from the Habitat Suitability tool the core and non-core patches (dark green) are identified.

Attributes of summary

OID	Type	FREQUENCY	MEAN_Area	SUM_Area	MEAN_Perim	SUM_Perime	MEAN_Per_1
0	Core	4	3591.71915	14366.8766	1457.47885	5829.9154	0.405282
1	Patch	1523	6.580999	10022.8611	7.08966	10797.5523	71.252146

Record: 1 Show: All Selected Records (0 out of 2 Selected)

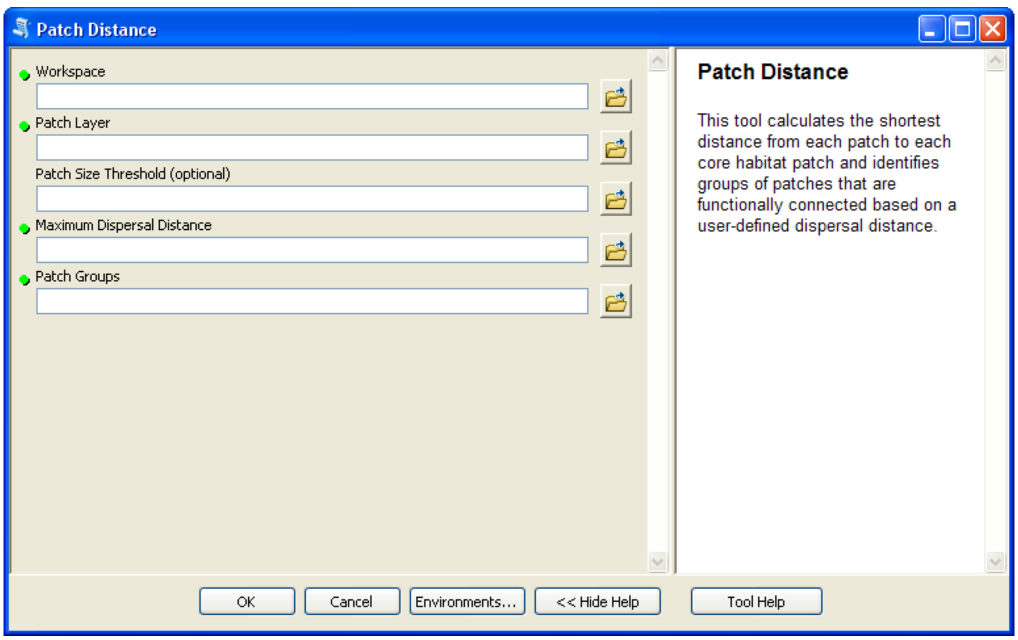
Figure 7. Sample patch summary table output from the Patch Statistics tool. The tool calculates number of core and non-core patches, mean area, total area, mean perimeter, total perimeter and mean perimeter-area ratio.

PART 6. Running the Patch Distance Tool

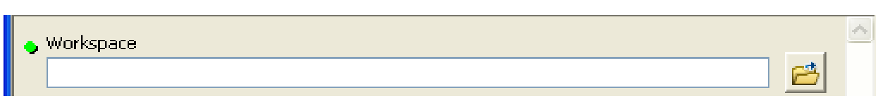
1. Double click the Patch Distance tool to open it. This tool requires you to select a workspace and the habitat patch layer previously created in the Habitat Suitability tool and modified with the Patch Statistics Tool. There is one output, the Patch Groups layer. In this, each patch will be grouped into connected 'regions' ('RegionID' column in the attribute table), and the core closest to each habitat patch will be identified ('CoreID' column in the attribute table). The distances in this tool are based on Euclidean distance, not habitat cost distance.

   If you run this tool in Arc10 without setting a minimum patch threshold, and are getting an output attribute table of mostly zeros, try running the tool again using a very small input threshold. This should allow the tool to run normally. If you do not want to use a threshold, make sure the input cell size is much smaller than the dispersal distance you use. Using an input size threshold in Arc9.3, however will take a very long time. This version of the tool should run fine without using a threshold.

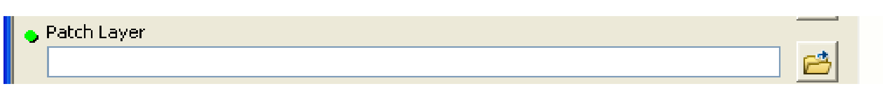
   *****If this tool returns an 'Error 99999, Invalid Topology' error, use the Check Geometry tool to check the patch layer for topological errors, and then use the Repair Geometry tool to fix the errors*****



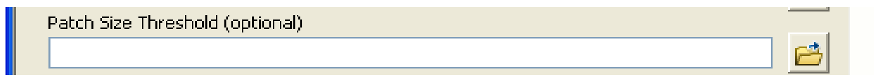
2. In the 'Workspace' box, click on the folder and navigate to the folder where you would like to store the output from this tool.



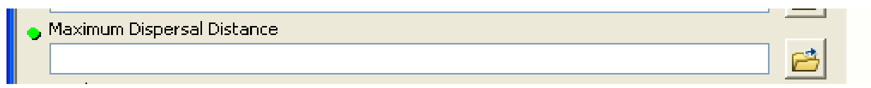
3. In the Patch Layer box, input the patch layer that was the output from the Habitat Suitability tool.



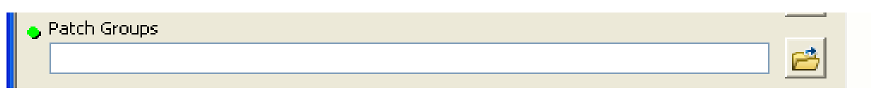
4. The Patch Size Threshold box is optional. Here, you can specify a minimum patch size (in km^2) that will be included in the analysis. If you are interested in seeing how patches of any size are connected, input the minimum size you want to analyze in this box. If the focal species only uses habitat patches greater than 500 km^2 for dispersal or as a stepping stone, input 500. If this option is used, the distance from each patch meeting the size requirements to the nearest core will be calculated. To include all patches in this analysis, input ‘1’ here. Using this option could be very time consuming. To speed up processing, leave this field blank. When this field is left blank, only the distance from each core to the nearest neighboring core will be calculated.



5. In the ‘Maximum Dispersal Distance’ box, type in the distance, in meters, that the focal species will travel to find new habitat, hunt, etc.



6. The final box is ‘Patch Groups’. This is the output shapefile from this analysis. The patches will look similar to the input layer, but the attribute table will include the 'RegionID', indicating to which other patches each patch is functionally connected based on the Maximum Dispersal Distance. The attribute table will also contain a 'NearDist' and 'CoreID' fields, which indicate the distance from each patch to the closest core (in kilometers) and which core each patch is closest to, respectively. The 'RegionID’ and 'CoreID' may be different if a patch is further than the Maximum Dispersal Distance from the closest core.



7. If you wish to delete the intermediate data, check the ‘Delete Intermediate Data?’ box.

Sample Output Attribute Table:

Columns from Patch Statistics (Area, Perimeter, PerimArea, Type)

Columns from Patch Distance (NearDist, CoreID, RegionID)

Attributes of patchgrps

FID	Shape *	GRIDCODE	Area	Perimeter	PerimArea	Type	NearDist	CoreID	RegionID
0	Polygon	14	391.0085	382.5007	0.978241	Patch	183.8083	1	2
1	Polygon	151	209.4078	307.2613	1.467287	Patch	142.849503	1	3
2	Polygon	265	496.4704	331.46	0.667633	Patch	45.036846	1	4
3	Polygon	295	747.6524	227.4168	0.304175	Patch	50.962809	1	6
4	Polygon	329	122.4489	135.8349	1.109319	Patch	57.694378	1	5
5	Polygon	269	1598.9695	396.7217	0.248111	Patch	0.311579	1	6
6	Polygon	369	1263.1866	308.6306	0.244327	Patch	10.032586	1	6
7	Polygon	487	162.2565	72.3467	0.445879	Patch	35.341904	1	6
8	Polygon	472	110.4434	146.4555	1.326068	Patch	0.997286	1	6
9	Polygon	829	1641.41	1084.6204	0.660786	Patch	0.079391	3	7
10	Polygon	1228	285.7766	288.9828	1.011219	Patch	9.992062	3	7
11	Polygon	1390	440.8391	451.881	1.025047	Patch	0.158359	4	7
12	Polygon	1449	252.1285	147.9558	0.586827	Patch	23.568694	4	7
13	Polygon	1491	220.795	189.6767	0.859062	Patch	30.69251	4	7
14	Polygon	377	4491.9085	1416.1115	0.315258	Core	48.131117	1	6
15	Polygon	758	1796.6961	580.3511	0.32301	Core	0.575713	2	7
16	Polygon	681	5782.0083	2700.525	0.467057	Core	7.499017	3	7
17	Polygon	942	3606.6863	2447.6834	0.678652	Core	0.575713	4	7

Record: 1 Show: All Selected Records (0 out of 18 Selected) Options

Smart Infrastructure Planner Appendix 1.
Including Dams in the Habitat Suitability Model

If you want to include dams into the Habitat Suitability Model, you may do so by identifying the area inundated by dams and incorporating this data into the land cover data. To do so, you will need a DEM (preferably 30m or 90m), the location of dams, and the height of dams.

It is recommended that you use the HydroSHEDS flow direction and DEM products for the most accurate results. Note that as with most DEMs, elevation is provided only in full meter resolution in the HydroSHEDS products, so calculation of inundation area with dams <15m in height may not be accurate. You may access HydroSHEDS data for free here: http://hydrosheds.cr.usgs.gov/

Completing the first two steps, Fill and Flow Direction, with your own DEM may result in incorrect outcomes. Make sure to check your results carefully. Errors in your results may be due to:

- A dam not being snapped to the correct stream
- Positional inaccuracies of the dam shapefile
- The use of an unfilled DEM to calculate flow direction
- The dam height is too low compared to the vertical resolution of the DEM

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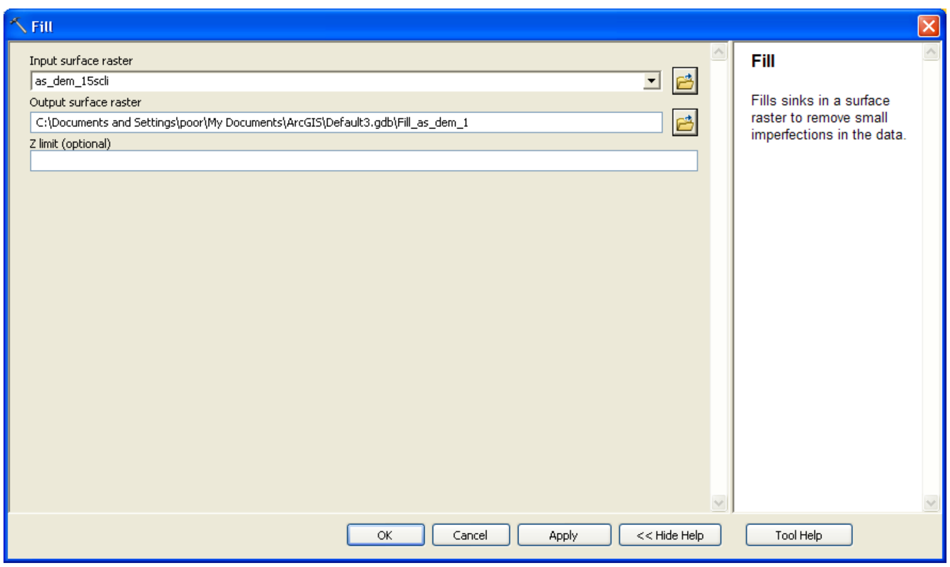
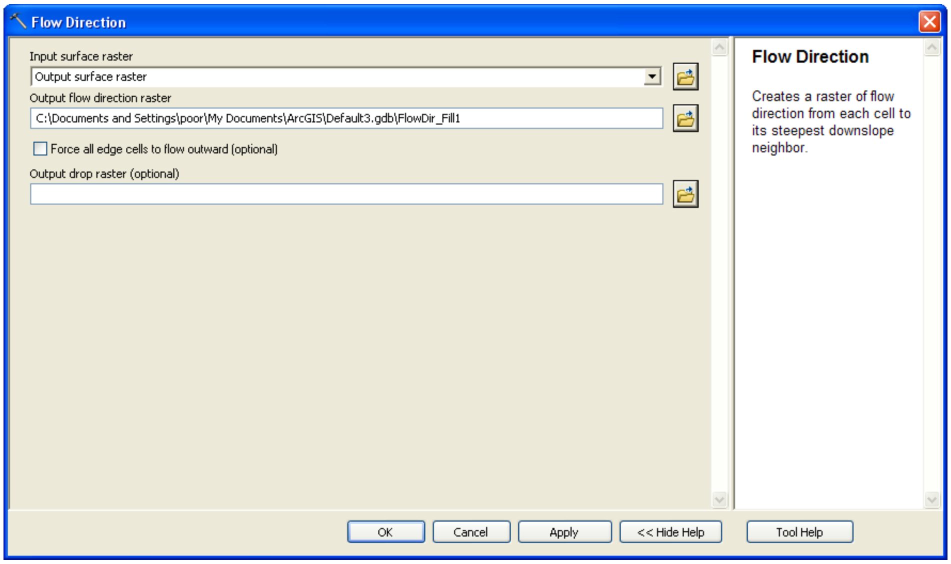
1. *(Optional: If you are using the HydroSHEDS flow direction product, skip to Step 3)* First, input your DEM into the Fill tool to ensure any holes are filled in.



2. Next, in the Flow Direction tool, input your filled DEM.



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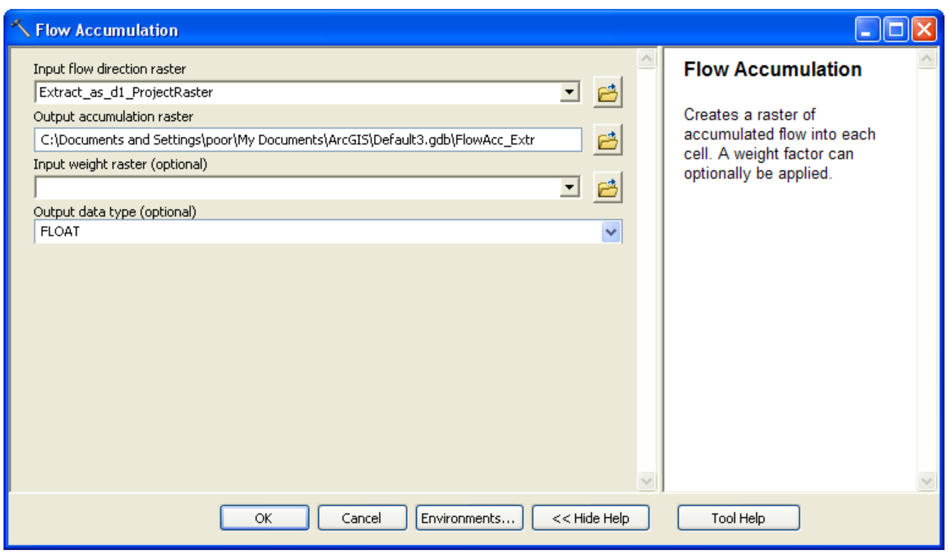
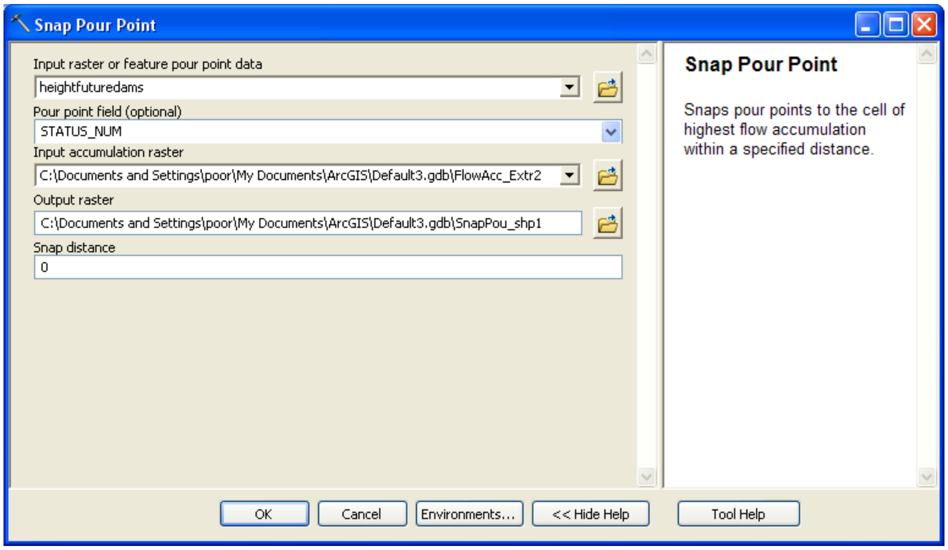
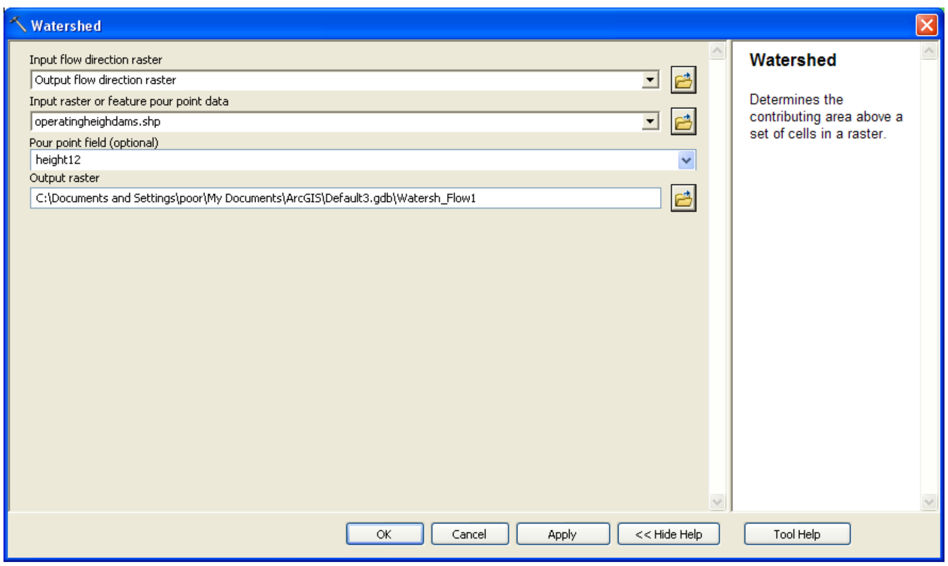
3. *Begin here if you are using the HydroSHEDS 3s flow direction product. If you are using a HydroSHEDS 15s flow accumulation product, skip to the next step.* Calculate the flow accumulation using the Flow Accumulation tool. Input the output from the Flow Direction tool to this tool. This tool may take a while to run.



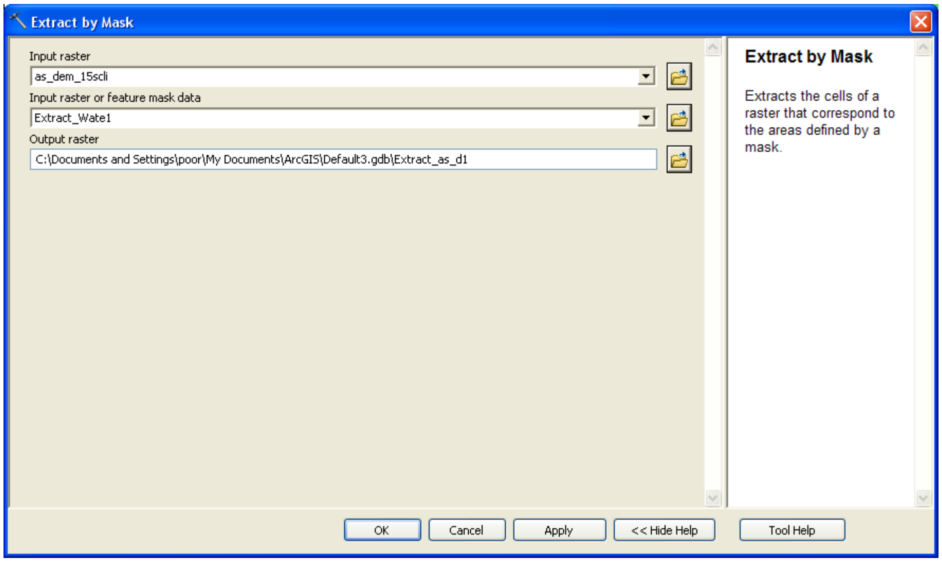
4. To snap the dams to the rivers, use the Snap Pour Point tool. Inputs to this tool will be your output from the Flow Accumulation tool (or the HydroSHEDS 15s flow accumulation raster layer) and the dams. Make sure your dams and flow accumulation raster are in the same projection.



5. Next, to identify the watersheds behind your dams, in the Watershed tool input the flow direction raster from HydroSHEDS (or the Flow Direction tool). In the ‘Input raster or feature pour point data’ box, navigate to your dams layer and click ‘Open’ to add it to the tool. In the next box, type in the name of the field from the dam attribute table that describes the dam height. This will label each watershed according to each dam’s height.

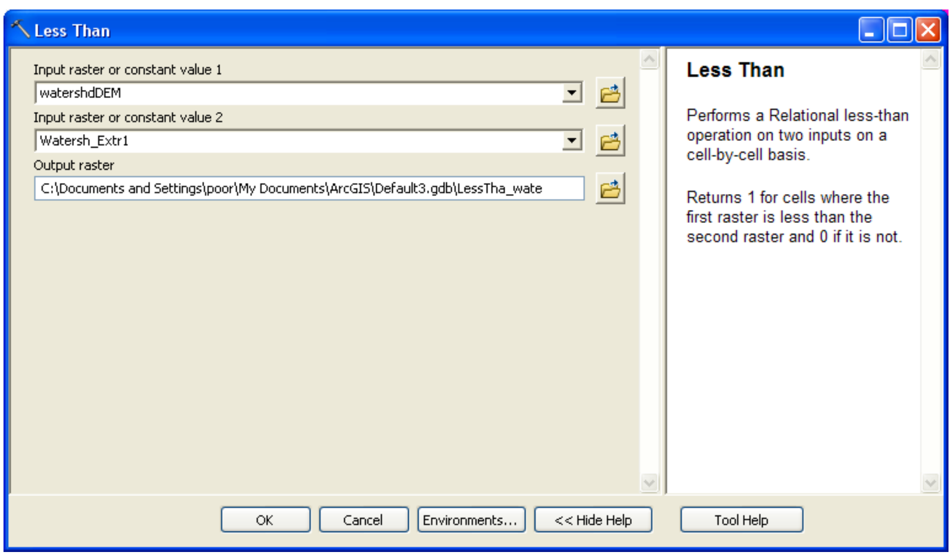


6. Once you have isolated the watersheds, use the Extract by Mask tool to clip the DEM to the watersheds.

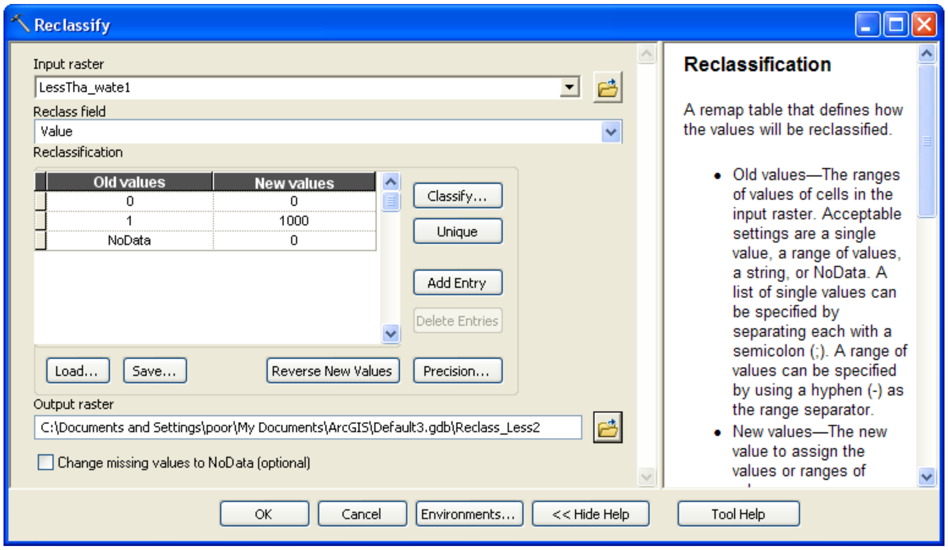


7. To identify the area of inundation from the dam, use the Less Than tool. As the first raster, input your DEM (preferably the HydroSHEDS DEM product), extracted by the watersheds. In the box for the second raster, input the watersheds raster layer. Areas shorter than the height of the dam will be labeled 1, and areas within the DEM that are taller than the dam height will be labeled 0 in the output raster layer. The areas with 1 represent areas that are lower than the dams within the watershed, and therefore, the areas of inundation. Areas labeled 0 will not be inundated.

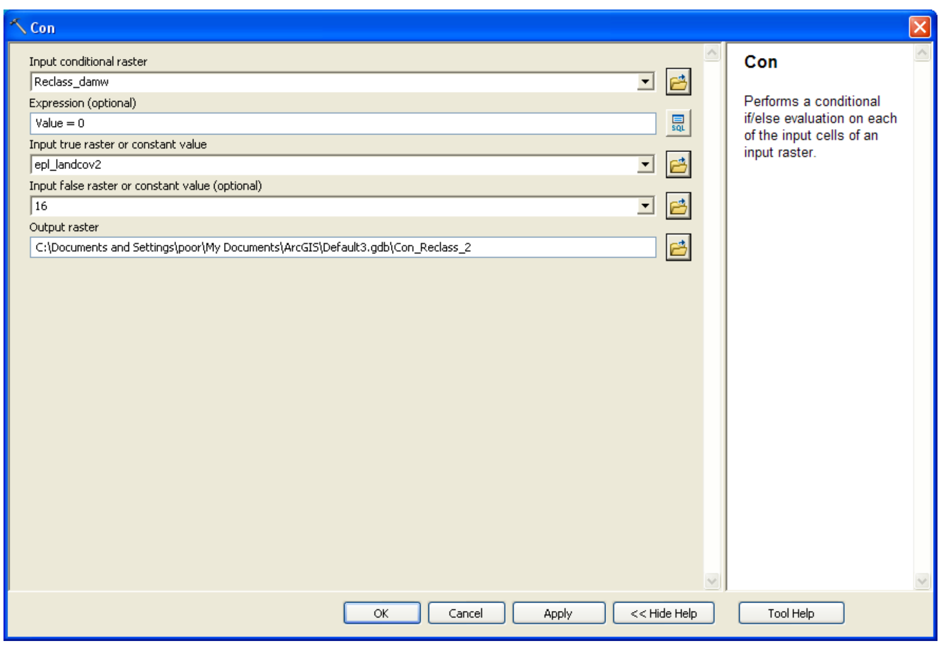
   Alternatively, you could subtract the watershed raster from the DEM using the Raster Calculator, Single Output Map Algebra or the Minus tool. Areas in the resulting raster that are greater than zero are not inundated and areas that are less than zero are inundated.



8. To prepare the resulting raster of inundated areas for integration into the land cover layer, reclassify the inundation raster to one value that is not within the land cover layer, and set the areas that are not inundated to Zero. Set the NoData values equal to zero.



9. Finally, use the Con tool to insert the inundated areas into the land cover dataset. The theoretical expression will be: Where the inundation dataset has a value of 0 (where there is no data or areas not inundated), insert the land cover dataset; where the inundation dataset is not zero (all of the inundated areas), set these areas to the land cover dataset's value for water (16 in the example below).



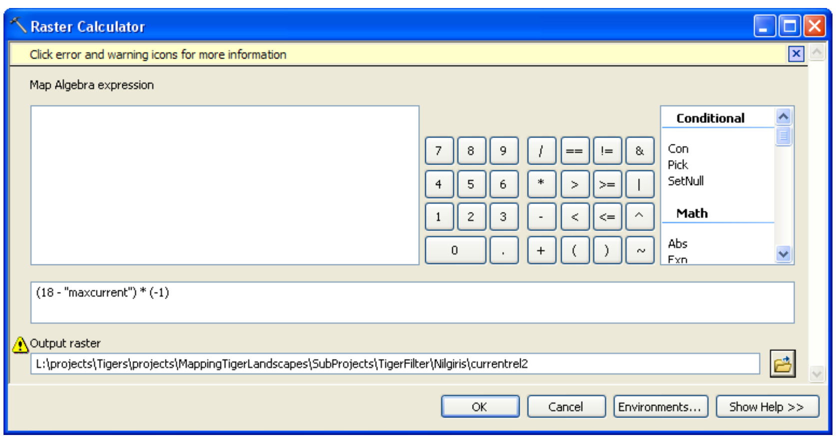
Make sure to check the attribute table of your newly formed land cover raster dataset. You may need to edit the attribute table to include the land cover classes as during raster processing, they may not have been preserved.

Smart Infrastructure Planner Appendix 2.
Substituting a MaxEnt Suitability Grid for the Expert-based Habitat Suitability Grid

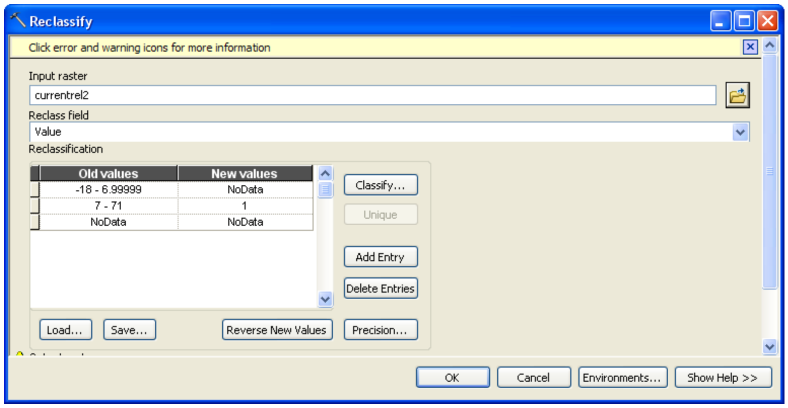
The most recent version of MaxEnt is free and may be downloaded from: http://www.cs.princeton.edu/~schapire/maxent/. MaxEnt should be run once, with your future data in a separate folder, with the Projections options, but the following process should be run twice; once for the current scenario and once for the future scenario. The parameters of the tools shown here are examples. You may change the parameters as you see fit.

1. In ArcGIS, after you have run MaxEnt, define the projection that was used in preprocessing prior to input to MaxEnt. This should be a planar projection.

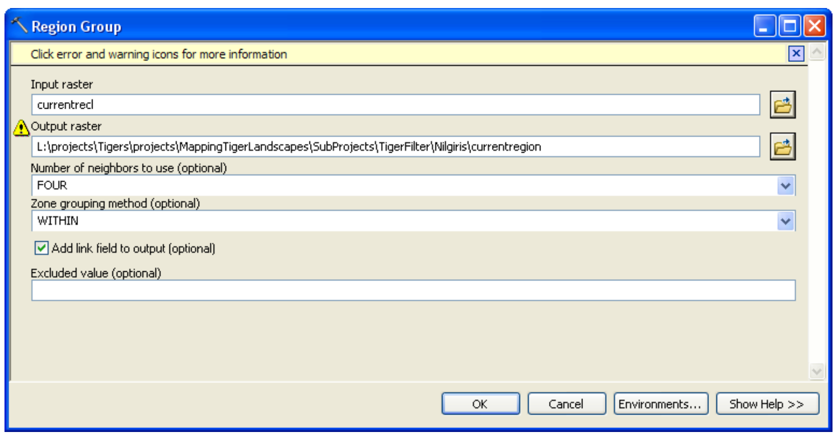
2. Standardize the MaxEnt output so the resulting high numbers represent suitable habitat areas and the low end of the scale represents non-suitable habitat. The scale should consist of positive values only. If you are comparing this output to output from the Habitat Suitability tool, the scale used here should be the same used for the Habitat Suitability tool (0-1000). If you are not using MaxEnt as a comparison, you may select the scale of your choice. High values should represent high probabilities of focal species/ecosystem occurrence (suitable habitat) and low values represent low probabilities of occurrence (unsuitable habitat). This may be done with the Raster Calculator in Arc10 and with the Single Output Map Algebra tool in Arc9.3 or lower.



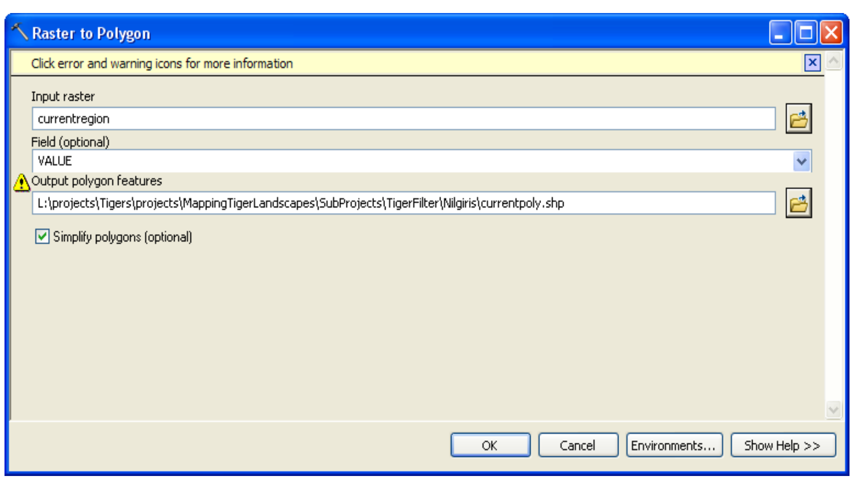
3. Identify the value defining ‘good’ habitat. You may select this value threshold by looking at occurrence data and threshold at a point above which all but about 5% of input points exist, or use the threshold chart in the MaxEnt output. Once you know the value above which is designated ‘good’ habitat, use the Reclassify tool to set all values below this to ‘No Data’ and all values above (or equal to) it to 1. The input here is the projected and standardized habitat suitability layer.



4. Using the Region Group tool, identify areas of ‘good’ habitat that are contiguous patches by inputting the output from the Reclassify tool. You may choose to define ‘contiguous’ by 4 cells touching the edges of a center cell or 8 cells touching the edges and the corners of a center cell. The 4 cell option is used in the Habitat Suitability tool. This option is recommended because it speeds up processing. The output of this tool will be a raster of habitat patches.



5. The output of the Region Group tool will be a collection of landscape patches that have been deemed ‘good’ habitat. Input this layer into the Raster to Polygon tool to convert the grid into a polygon layer.



6. If you wish to further analyze the distribution of habitat on the landscape, you may input the Patch layer into the Patch Statistics tool. This tool will identify 'core' and 'non-core' patches (based on a user defined area), total area, average area, average perimeter and the perimeter to area ratio of each type of patch. For more detailed instructions on the use of this tool refer to the Smart Infrastructure Planner Toolkit User Guide.

Smart Infrastructure Planner Appendix 3.
Identifying Least-cost Movement Corridors between Patches

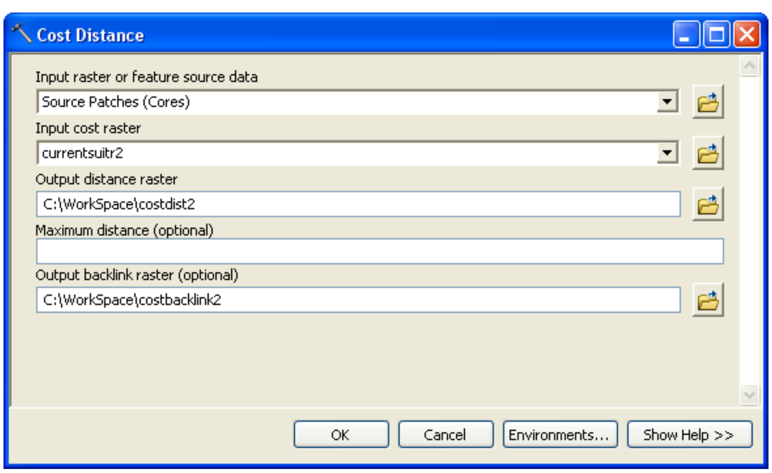
****This workflow may take several hours or the entire day to complete, depending on cell size and the size of your study area. To increase speed, increase cell size and decrease the size of your study area. The main inhibitor is the Cost Path tool****

This is included as an Appendix because identifying corridors and changes in corridors can be an important factor when looking at landscape change. Our SIP tools do not provide this type of analysis because ArcGIS provides a somewhat straight forward analysis. If all of the corridor tools where provided in one tool within the toolset, processing time would be prohibitive. The Patch Distance tool identifies patches that are 'connected' based on the maximum dispersal distance, but does not specifically identify the general paths an animal would take from one patch to the next. Keeping these corridors intact is integral for maintaining gene flow and a healthy breeding population of focal species.

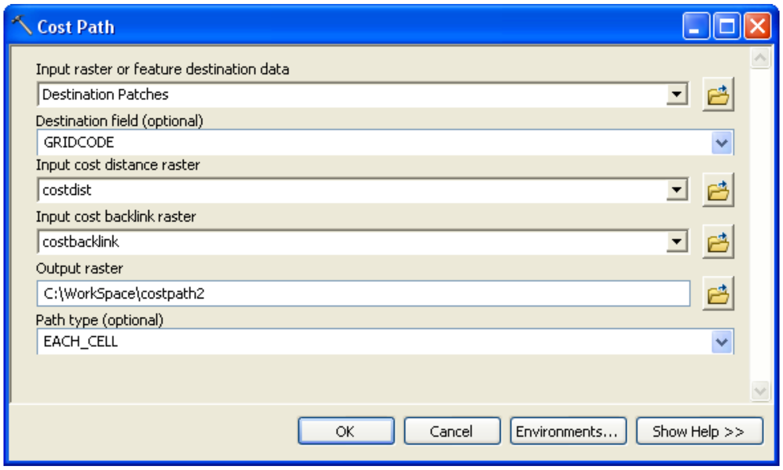
1. Convert your habitat suitability grid resulting from the Habitat Suitability tool to a cost-surface. To do this, you may use the Raster Calculator (Arc10) or Single Output Map Algebra (Arc 9.3) tools to invert the values of the suitability layer by subtracting the layer from 1000. Now, the high values indicate high 'cost' to traverse this landscape, or low quality habitat, and the low values represent low movement 'cost', or high quality habitat.

2. Decide what patches are your 'source' patches; patches that contain breeding populations of your focal species that disperse into the landscape. It is recommended you use the 'Cores' as the source patches. Decide which patch are the 'destination' patches. These are areas where your focal species moves to from the source areas. It is recommended you use the non-core patches for the destination patches. If you are interested in seeing all of the paths from every core patch to every non-core patch, input the cores separately as 'source' patches, and run the process once for each different core. In doing so, retain all of the non-core patches as destination patches.

3. In the Cost Distance tool, input the layer you've selected to use as the 'source' patches into the 'Input raster or feature source data' box and input the cost surface just created into the 'Input cost raster' box. Select a name for the 'Output distance raster' and the 'Output backlink raster'. The output distance raster will be a raster layer describing how difficult it is for your focal species to move across a land in terms of habitat quality.



4. After the Cost Distance tool completes, run the Cost Path tool. In the ‘Input raster or feature destination data’, input the layer you’ve chosen to use as the destination patches (the non-core patches). The more destination patches you use, the longer the analysis will take. To save time you may want to select those non-core patches that are large enough to be used by your focal species, by using the threshold you selected for the Patch Distance tool. Use the two output raster files from the Cost Distance tool for the ‘Input cost distance raster’ and the ‘Input backlink raster’. Select a title for the resulting cost path layer. The result will be a least-cost path from the source patches to the destination patches. For easier viewing, you may convert the resulting least-cost path raster file to polygon layer (use the ‘Simplify Polygons’ layer).



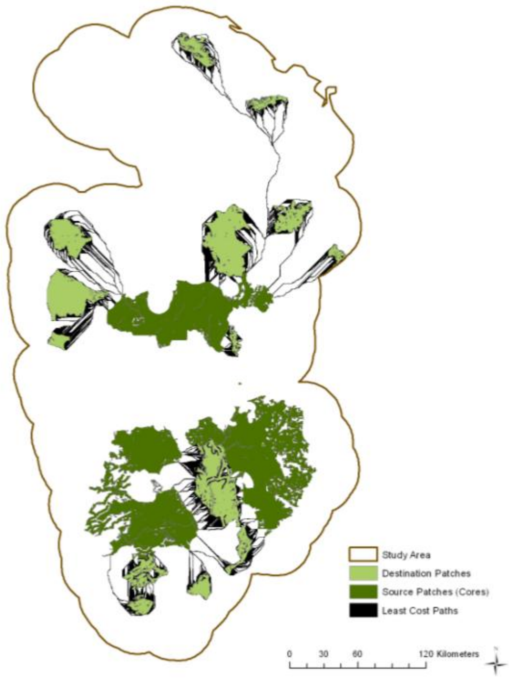


Figure 8. Example result from a Least-cost Path analysis. Cores were used as 'sources' and non-core patches were used as the 'destination' patches.