American Museum of Natural History
Center for Biodiversity and Conservation
Network of Conservation Educators & Practitioners

Modeling Suitable Habitat for a Species of Conservation Concern: An Introduction to Spatial Analysis with QGIS

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b. Using an expression[4] string, select the features of the "USA" layer that correspond with the attribute "New York." In the Attribute Table, click on "Select features using an expression." In the search bar, type "name" and double click on "name" in the window. It will appear in the Expression window. Click on the equals sign "=" above the Expression window. On the right side of the window is another search bar, "Values," where you can search values within each field. Here, type in "New York," then click "All Unique." Double click on the field 'New York' and it should appear in the Expression window. Click "Select features." On the map, New York State will be highlighted in yellow. Close the "Select by Expression" dialogue box.

c. Back in the Attribute Table, in the lower left corner, change "Show All Features" to "Show Selected Features." The row with data for New York State should be highlighted.

d. Close the Attribute Table and inspect the map. New York should be highlighted. Right-click on the "USA" layer in the Layers panel and select "Zoom to Selection." The map should jump to New York.

e. To save the selection as its own layer, right-click on the layer in the Layers panel. Select "Export," then "Save Selected Features As." In "Format," select "ESRI shapefile." Navigate to the working directory by clicking on the ellipsis button next to the "File name" field. Name the file "NewYorkState" in the "Save As" field and hit "Save." You will not need to change anything else in the dialogue box. Click "Ok" and the new layer will be added to the map.

   Tip: To avoid confusion with multiple similar layers, remove the "USA" layer by right-clicking on it and selecting "Remove Layer."

   Note: You should always use the ellipses button to navigate to your working directory when creating a file and name the file in the "Browse" dialogue box to make sure your files are all located in one place.

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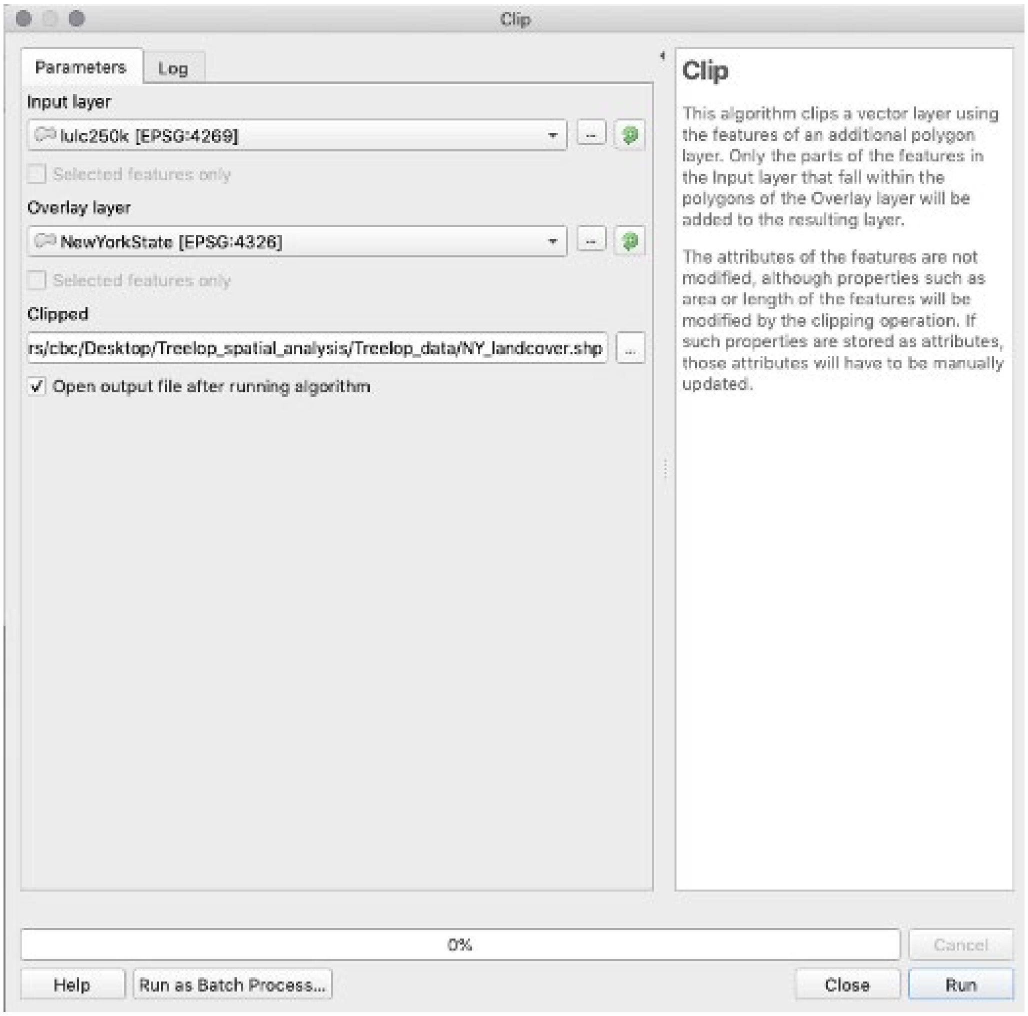
4. Next, we want to clip the land cover ("lulc250k") and major roads ("ne_10m_roads") layers to the extent of the New York State shapefile (we have already provided the "Treelop_sightings" data for New York State sightings only). To choose New York State in the USA shape file, we only had to use the Attribute Table because "States" was one of many attributes in the file. The other files, however, do not have an attribute that would allow us to choose them by state, and, therefore, we must use other tools in order to clip the data that we need.

   a. Clip the land cover layer: Go to Vector > Geoprocessing Tools > Clip. Since we are interested in clipping the landcover layer ("lulc250k"), select it as the "Input layer," and the "NewYorkState" shapefile as the "Overlay layer." Under "Clipped," click on the ellipsis button, and select "Save to File." Name the new file "NY_landcover" and make sure that the file will be saved in your working directory (rather than the default output folder). Then make sure that you select "SHP files (*.shp)" instead of the default "GPKG files (*.gpkg)" in the dropdown menu at the bottom of the dialogue box (GeoPackage files are in a standard, non-proprietary file format that is compatible QGIS but may not be readable by other GIS software). Click "Save," then "Run." The clipped layer will automatically add to your Layers panel named as "Clipped." Close the dialogue box and rename the "Clipped" layer to match the filename ("NY_landcover") by right clicking on the layer in the Layers panel and selecting "Rename Layer."

      Tip: if you add ".shp" to the filename it will automatically select shapefile as the output format.

      Note: If the "Vector" tab does not appear on the main toolbar, you will need to update all plugins. To update, go to Plugins > Manage and Install Plugins. Then click the button "Upgrade All." The "Vector" tab should now be available.



b. Repeat the clip procedure for the major roads layer ("ne_10m_roads"), naming it "NY_roads".

c. After clipping the layers, select the check-boxes in the Layers panel to show only the newly clipped layers.

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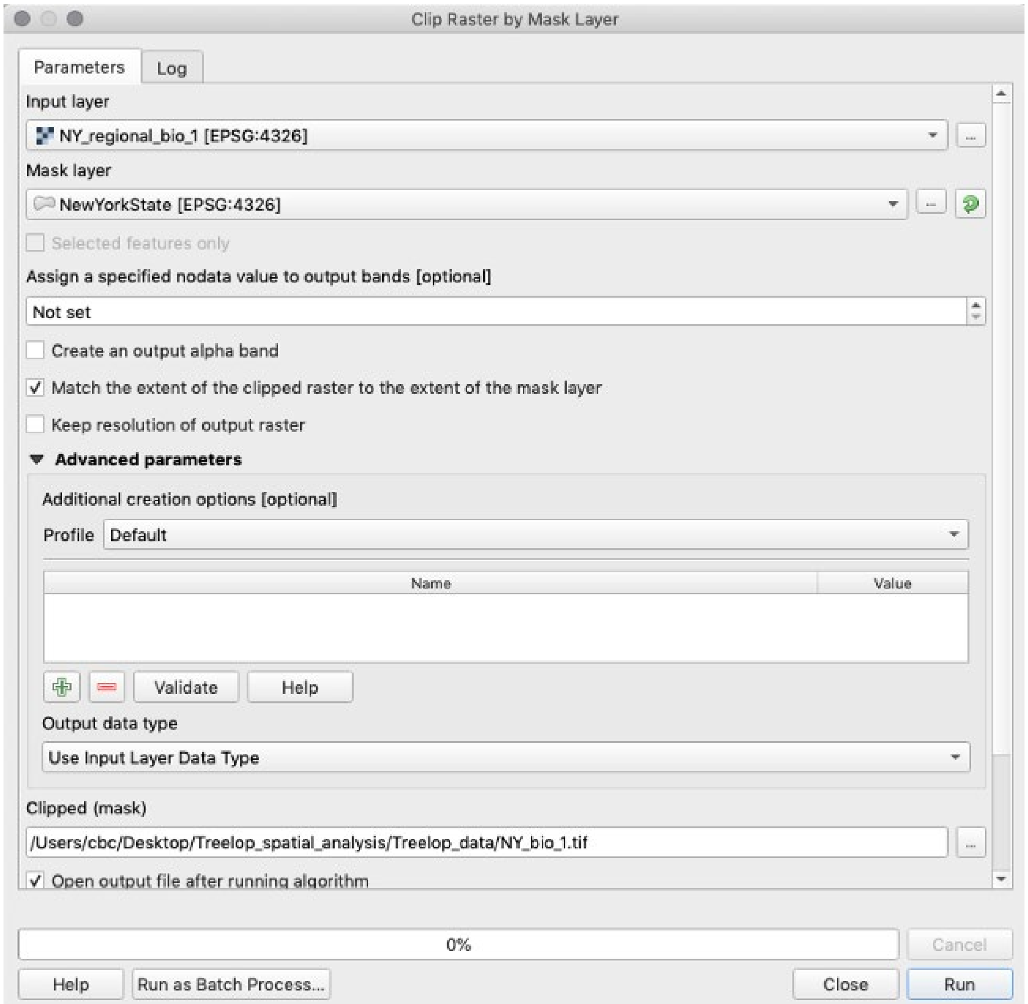
5. Crop the Mean Annual Temperature raster to the New York State shapefile. All previous files were in vector format (see glossary). The temperature data is in raster format, so we need to use a different tool in order to clip the layer.

   a. Go to Raster > Extraction > Clip Raster by Mask Layer. Set the "Input layer" to "NY_regional_bio_1" and the "Mask layer" to "NewYorkState." Click the ellipses next to "Clipped (mask)" and then "Save to File" and set the file directory. Name this new raster file "NY_bio_1." Save in .tif format. Click "Run" (**Note**: you may need to scroll down the dialog box to view all options.)
   b. Close dialogue box and rename the "Clipped (mask)" layer on the Layers panel to match the new raster file name ("NY_bio_1").

   c. **Important**: the newly clipped raster will draw on your map over the previous NY clipped layer. You can reorder the layers in your Layers panel so they draw on the map in a different order (allowing you to see them all clearly). Simply drag and drop the newly clipped layers in the Layers panel to your preferred order.



Tip: To quickly find a tool by its name, you can activate the Processing Toolbox: go to View > Panels > Processing Toolbox Panel. Here you can type in a tool's name and select.

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PART 4: ANALYZING THE DATA

Spatial Analysis

Now that we have layers that are specific to New York State, we can begin the analysis for our report. Until this point, we have been "cleaning up the data." Now, we want to use spatial analysis to answer questions.

In this part of the exercise, we will walk you through the spatial analyses steps, but if you were doing this on your own, you'd want to consider the following: how can you use these data to give an assessment of potential survey locations? Given what we know about Treelopi, what are some processes/tools you could use to analyze the data? How might the data interact and inform us about where we could find Treelopi?

Reflection

Brainstorm and write down your thoughts on these prompts. If there are other questions you have, what are they?

Let's begin analyzing our data and create a visual output that can show us potential suitable habitats for Treelopi that match what we know about the species (refer to the first page of this exercise).

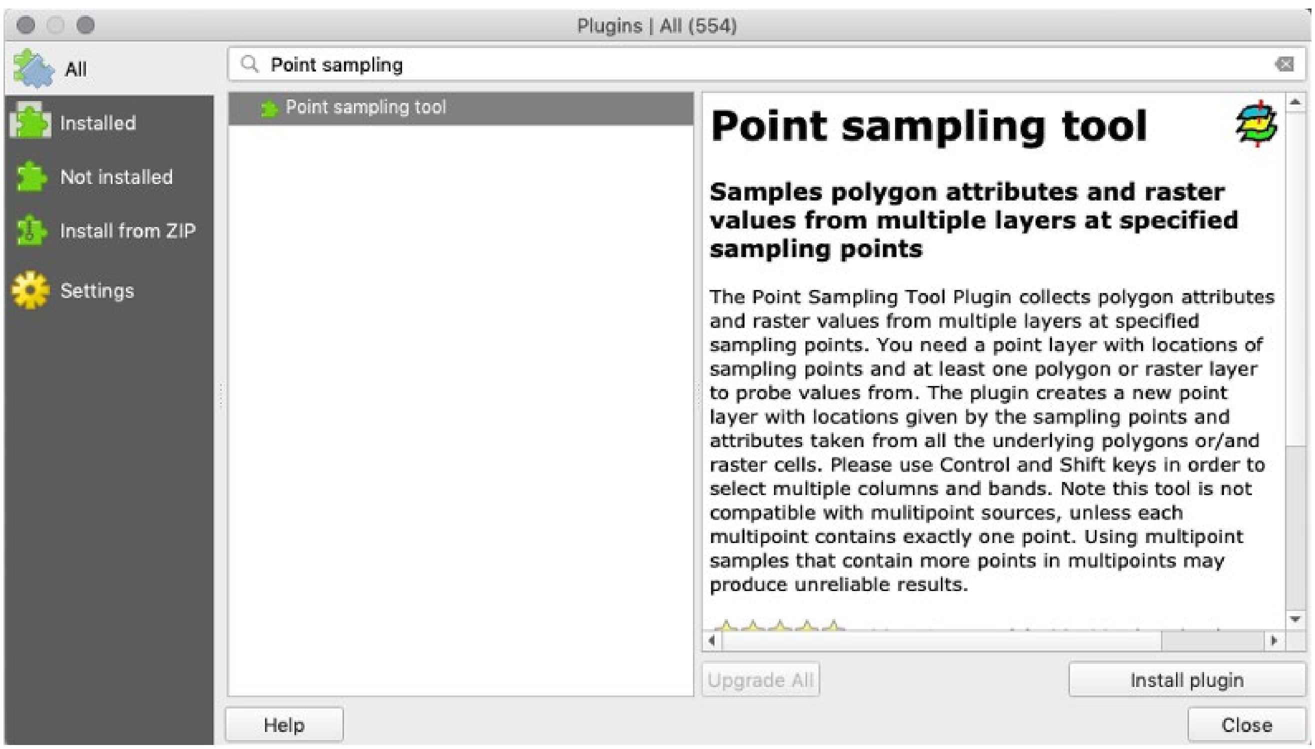
Steps:

4.1 Analyze climate data: Identify areas of New York State with suitable temperature for Treelopi.
4.2 Analyze habitat data: Identify areas of suitable habitat from land cover data.
4.3 Analyze road data: Determine areas of New York State that are not adjacent to major roads.
4.4 Identify the areas of overlap where there is suitable climate, habitat, and distance from roads.

4.1 Analyze the Climate Data

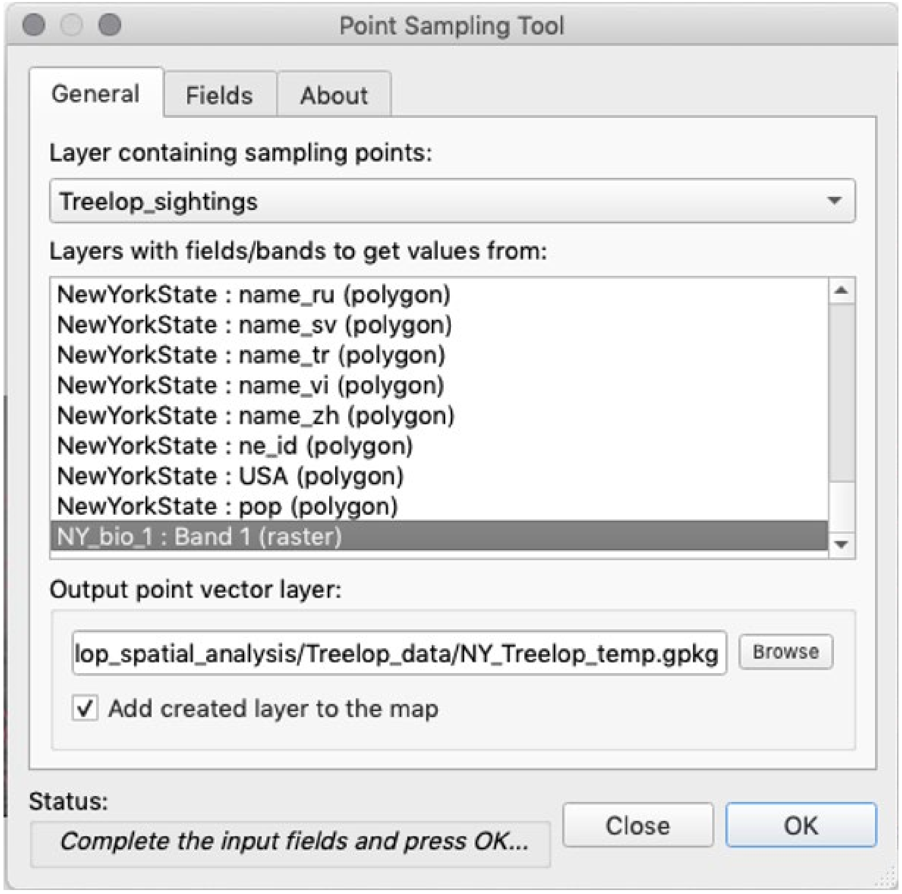
1. We want to determine the areas with suitable mean annual temperatures for Treelopi. To do so requires several steps. We have sightings of Treelopi across New York State, and we can make the assumption that the mean annual temperatures associated with those locations are suitable for the species. Therefore, the first step is to reduce the raster of mean annual temperature to show only those areas that are within the temperature range in which Treelopi have been recorded.

   For this step, we'll need to install a plugin. Plugins are a way for QGIS developers to increase the utility of the software past the base QGIS download. Go to Plugins > Manage and Install Plugins. In the "All" tab on the left, search for the "Point sampling tool" then click "Install plugin." When the installation is over, close the dialogue box.

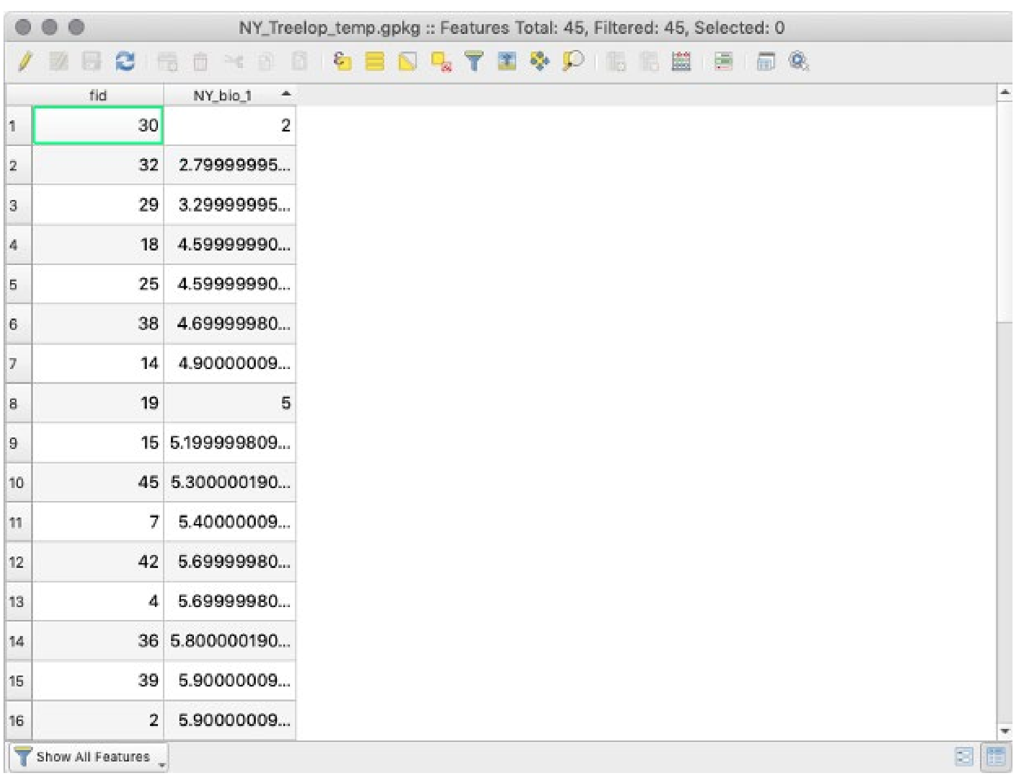


2. Next, we will extract the temperature values from "NY_bio_1" where Treelop has been seen.

   a. Select the "Treelop_sightings" layer in the Layers panel. Then, go to Plugins > Analyses > Point Sampling Tool. Select the "Treelop_sightings" layer for "Layer containing sampling points" (this should be selected by default). For "Layers with fields/bands to get values from," select "NY_bio_1." Make sure the "Add created layer to the map" box is checked. Navigate to your chosen file directory by clicking "Browse" next to "Output point vector layer." Save the file as "NY_Treelop_temp" with the extension of a GeoPackage file (.gpkg). Again, GeoPackage files are in a standard, non-proprietary file format that is compatible QGIS, but may not be readable by other GIS software. Here, we will use it only for this step. Click "OK." Once the new layer has shown up on the Layers panel, click "Close" to close the dialogue box.



b. Open the Attribute Table of "NY_Treelop_temp." Examine the values of Mean Annual Temperature ("NY_bio_1" column) for each locality of a Treelop sighting. **Tip**: You can sort the values in ascending or descending order by clicking on the field (column) header.



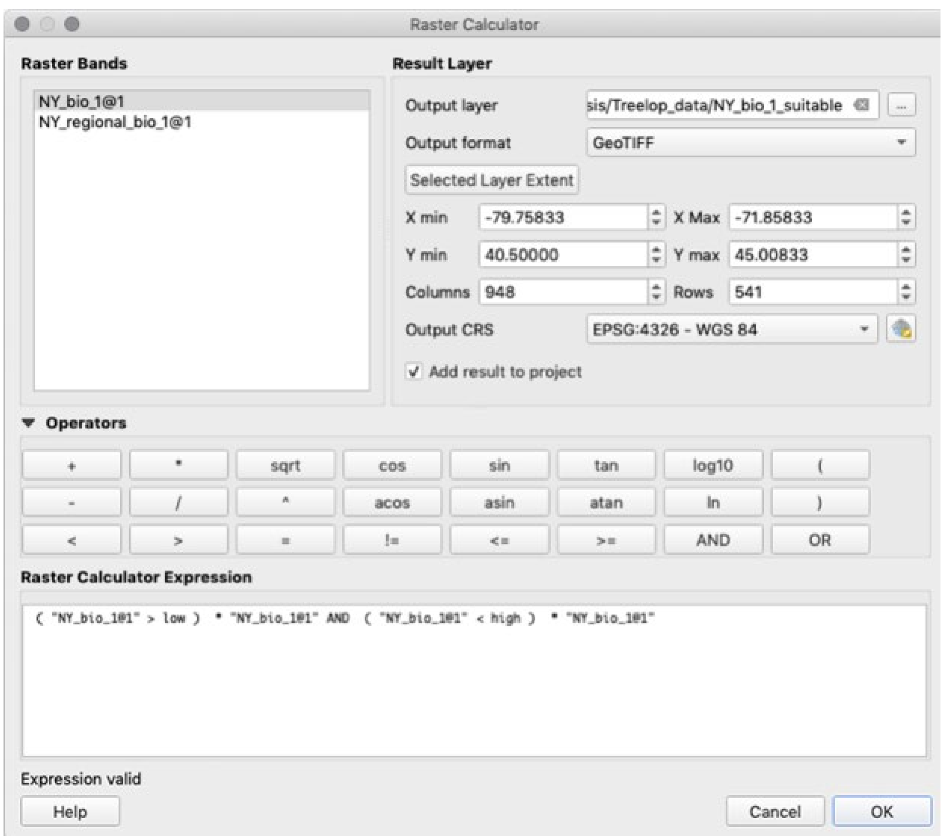
	fid	NY_bio_1
1	30	2
2	32	2.79999995...
3	29	3.29999995...
4	18	4.59999990...
5	25	4.59999990...
6	38	4.69999980...
7	14	4.90000009...
8	19	5
9	15	5.199999809...
10	45	5.300000190...
11	7	5.40000009...
12	42	5.69999980...
13	4	5.69999980...
14	36	5.800000190...
15	39	5.90000009...
16	2	5.90000009...

3. To determine what is the Treelop's preferred temperature range, we are only interested in the minimum and maximum mean annual temperatures observed for Treelopi. Sort the observed mean annual temperatures by clicking on the header in the Attribute Table. Click once to sort by the lowest mean annual temperature associated with a Treelop sighting and click the header again to see the highest mean annual temperature for a Treelop sighting. Our assumption is that areas outside of this range of temperature values are not suitable for Treelop.

    a. Record the values. Round the minimum value down to the nearest full degree Celsius. Round the maximum value up to the nearest full degree Celsius. We will round down and up to ensure that all sighting points are included within the range while also erring toward a conservative estimate of suitable areas.

    b. We assume that only areas within this range are suitable for Treelopi; areas where we should be focusing our efforts. We will remove what we assume to be the unsuitable areas from the map by setting values below the minimum and above the maximum temperatures where we have Treelop occurrences to "nodata" (meaning there is no data associated with areas outside this range of mean temperatures). The rest of the values (within the minimum and maximum range) will be set to "1" to denote that it is "suitable." This will leave all of the geographic areas with suitable temperature on the map, while removing areas not within the suitable temperature range.

    c. Using the Raster Calculator: Using a logic string and minimum and maximum values you observed in the Attribute Table from the step above, you will create a raster showing all areas of New York State that have suitable (1) and unsuitable (0) temperatures (a binary raster mask). Open the Raster Calculator by going to Raster > Raster Calculator. Enter in the formula below in the "Raster Calculator Expression" field, with "low" being the recorded minimum mean annual temperature and "high" being the maximum. DO NOT type in symbols; use the operator buttons and the items under "Raster Bands" whenever possible.
    (NY_bio_1@1 > low)*NY_bio_1@1 AND (NY_bio_1@1 < high)*NY_bio_1@1



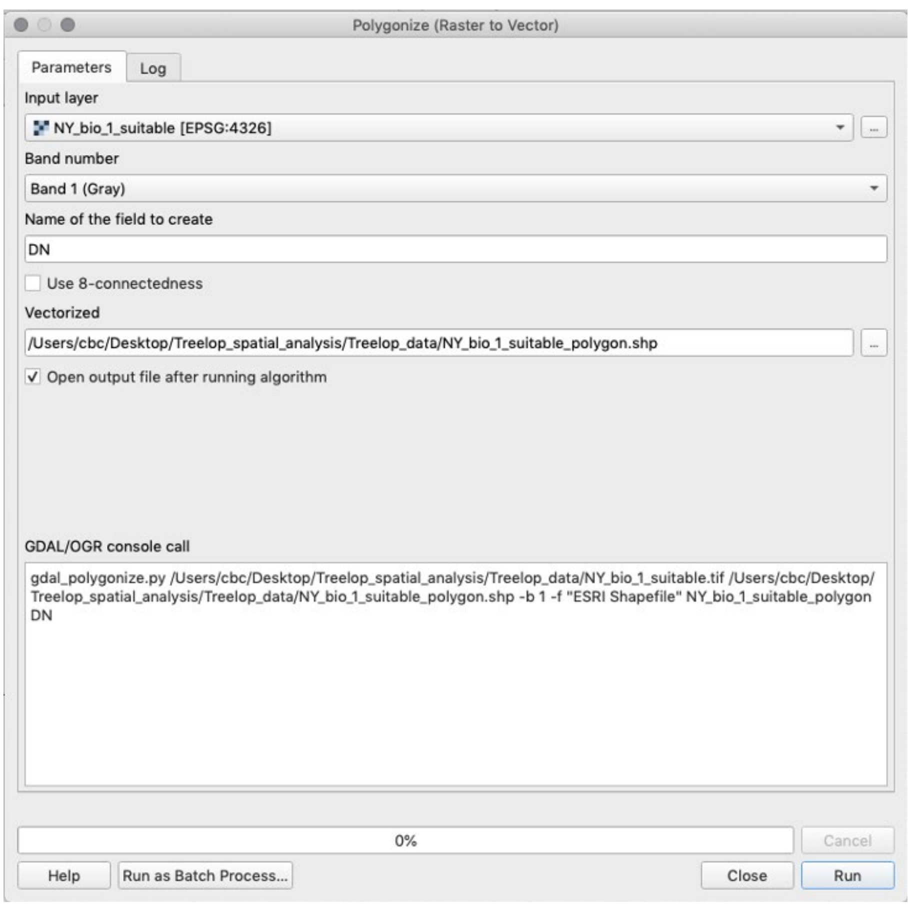
d. Click the ellipsis button next to the “Output layer” field to select your working directory and name this file “NY_bio_1_suitable” and click “Save.”

e. In the “Raster Calculator” dialogue box, make sure the “Output format” is in .tif format (“GeoTIFF”). **Note**: after filling out the expression, “Expression valid” should appear in bottom left corner of the calculator. If “Expression invalid” appears, you will not be able to perform the calculation. Click “OK” and view the areas of New York State that have unsuitable temperatures for Treelop (in black).

4. We now have, what we assume to be, the temperature-appropriate areas for Treelopi in raster format. The rest of our data (i.e., land cover, roads), however, are in vector format. To be able to perform the future steps of our analysis, we will convert this binary raster—with suitable areas as the value 1 and unsuitable areas as the value 0—into a shapefile (specifically into a polygon[5], which is a vector data type). **Note**: we could clip a raster by a vector layer and omit these steps, but the computer processing time can be prohibitive, so we will do the conversion instead.

For this new polygon, we want to focus on only the suitable areas (denoted by the value 1), therefore, for simplicity, we will delete all the areas with a value of 0. After we convert the raster into a polygon, we will delete the geometries (rows in the attribute table) showing the value 0 (unsuitable area) and save the edited polygon.

a. Go to Raster > Conversion > Polygonize (Raster to Vector). Input the “NY_bio_1_suitable” layer for “Input layer.” Next to “Vectorized,” click the ellipsis button, “Save to File,” set file directory and name it “NY_bio_1_suitable_polygon.” Be sure to switch the file extension to a shapefile (.shp file) rather than a geopackage (.gpkg file). Click “Save” and then click “Run.”

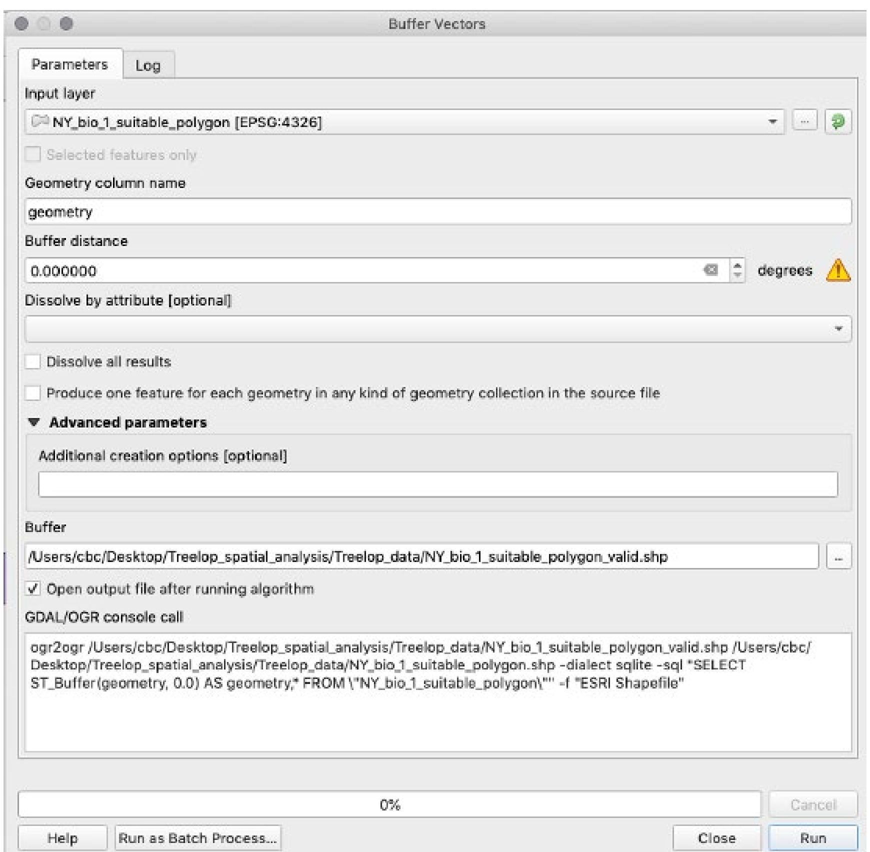


b. The layer will draw to your map and be automatically given the named “Vectorized” in the Layers panel. Rename it to match the file name (“NY_bio_1_suitable_polygon”).

c. You will notice that this polygon does not look like the original raster of suitable areas. To fix this, delete polygons that are not equal to 1. Click on the polygon layer “NY_bio_1_suitable_polygon,” and view its Attribute Table. Click “Toggle editing mode.” Click on the “DN” field (column) header to sort. Select all rows with a DN value not equal to 1. Click “Delete selected features” to delete these entries. Click “Toggle editing mode” again, and save changes.

d. It is not uncommon for GIS to have some issues when going through analyses (especially conversions). In this case, the software encounters a problem with the process of drawing the polygons that are on the edges and some of them are, therefore, considered “invalid.” There is a fix to this issue, which is forcing the software to redraw the polygons. To do this, we will make a new layer that takes the polygon and buffers the geometries by 0 (meaning no addition or subtraction). This will redraw the polygon with no invalid geometries.

   i. Go to the “Toolbox” on the right-hand side of the screen or alternatively go to Processing > Toolbox. In the search bar, type in “buffer” and under “Vector geoprocessing,” click on “Buffer vectors.” Select the correct “Input layer” (“NY_bio_1_suitable_polygon”), and set “Buffer distance” as 0. Save as a shapefile named “NY_bio_1_suitable_polygon_valid” by clicking on the ellipses next to “Buffer.” Click “Run.”



   ii. Close the dialogue and rename the new layer “Buffer” to match the file name (“NY_bio_1_suitable_polygon_valid”).

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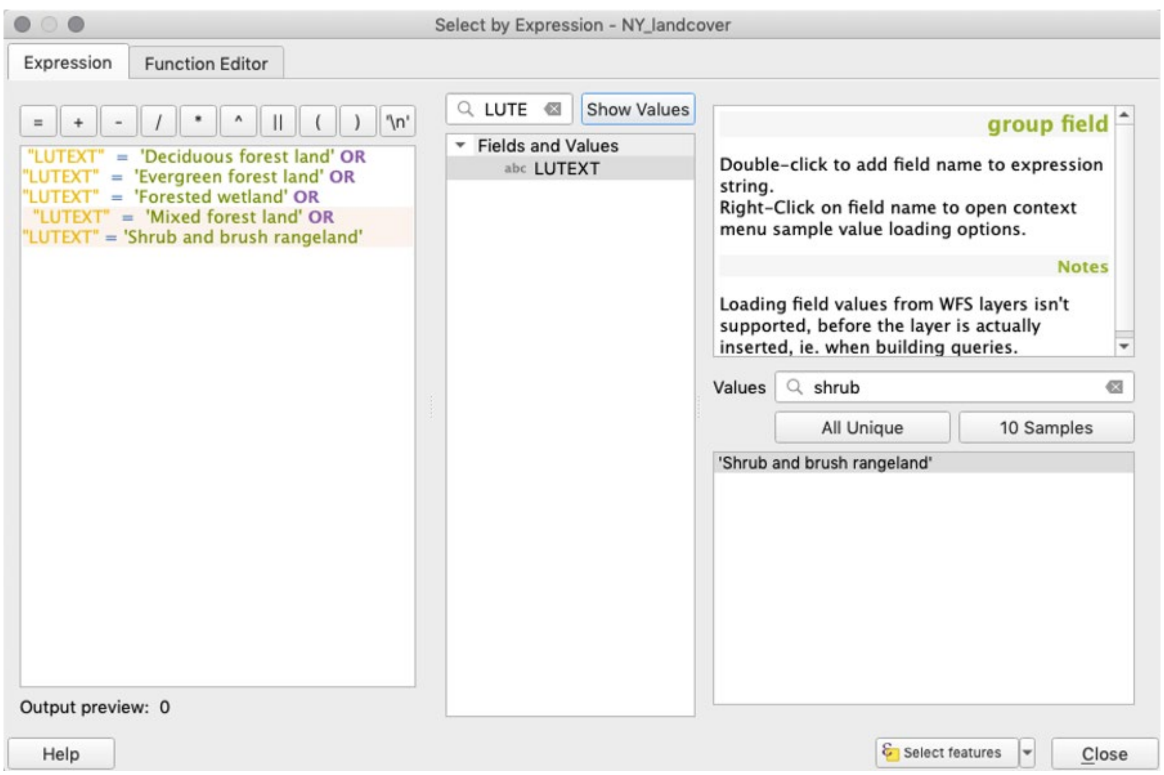
4.2 Analyze the Habitat Data

In the previous steps, we created a shapefile (vector format) layer of all the areas in New York State that have suitable temperature ranges for Treelopi. We also know, from the few natural history studies of this species, that Treelopi also prefer certain kinds of habitats. In this next step, we extract only those areas from our land cover layer that are preferred and create a new shapefile. To do so, we will use logical operators and expressions to select attributes that match what we know about Treelopi. Logical operators such as "and," "or," "not," or "equal to" can be used to select attributed that fulfill our needs.

1. Navigate to the Attribute Table of the land cover layer, "NY_landcover." Explore the Attribute Table, especially the column labeled "LUTEXT" (stands for "Land Use Text"). This column shows land cover type for each geometery (polygon feature) in New York State. Given what we know about Treelopi (e.g., prefer forested areas), which land cover types do you think we should include?

2. Click the "Select features using an expression" icon. Considering that Treelopi prefer natural areas (non-agricultural lands), are forest generalists, and are often associated with woody vegetation, write an expression using "OR" that satisfies the conditions where the field "LUTEXT" is either "Deciduous forest land," "Evergreen forest land," "Forested wetland," "Mixed forest land," or "Shrub and brush rangeland." Remember to use the search bar in the middle panel of the dialogue box to select your column of interest (double-click), use the search bar and "All Unique" button to select your variable of interest for that field, and use the expression buttons above the "Expression" box while writing your expression. Click "Select features." Click "Close" to close the dialogue box. Notice these features are now selected on the map of land cover.



3. To create a new shapefile from this new selection, right-click on the "NY_landcover" layer in the Layers panel and select "Export," then "Save Selected Features As." Export as a new shapefile named "Treelop_preferable_landcover" (be sure to save in your working directory). **Note**: Often in QGIS, processes have more than one solution. Exporting selected features in this way will result in the same outcome as deleting features that are NOT of interest (as in step 4.1.4).

Reflection
What are some ways this important alternative might be useful to know?

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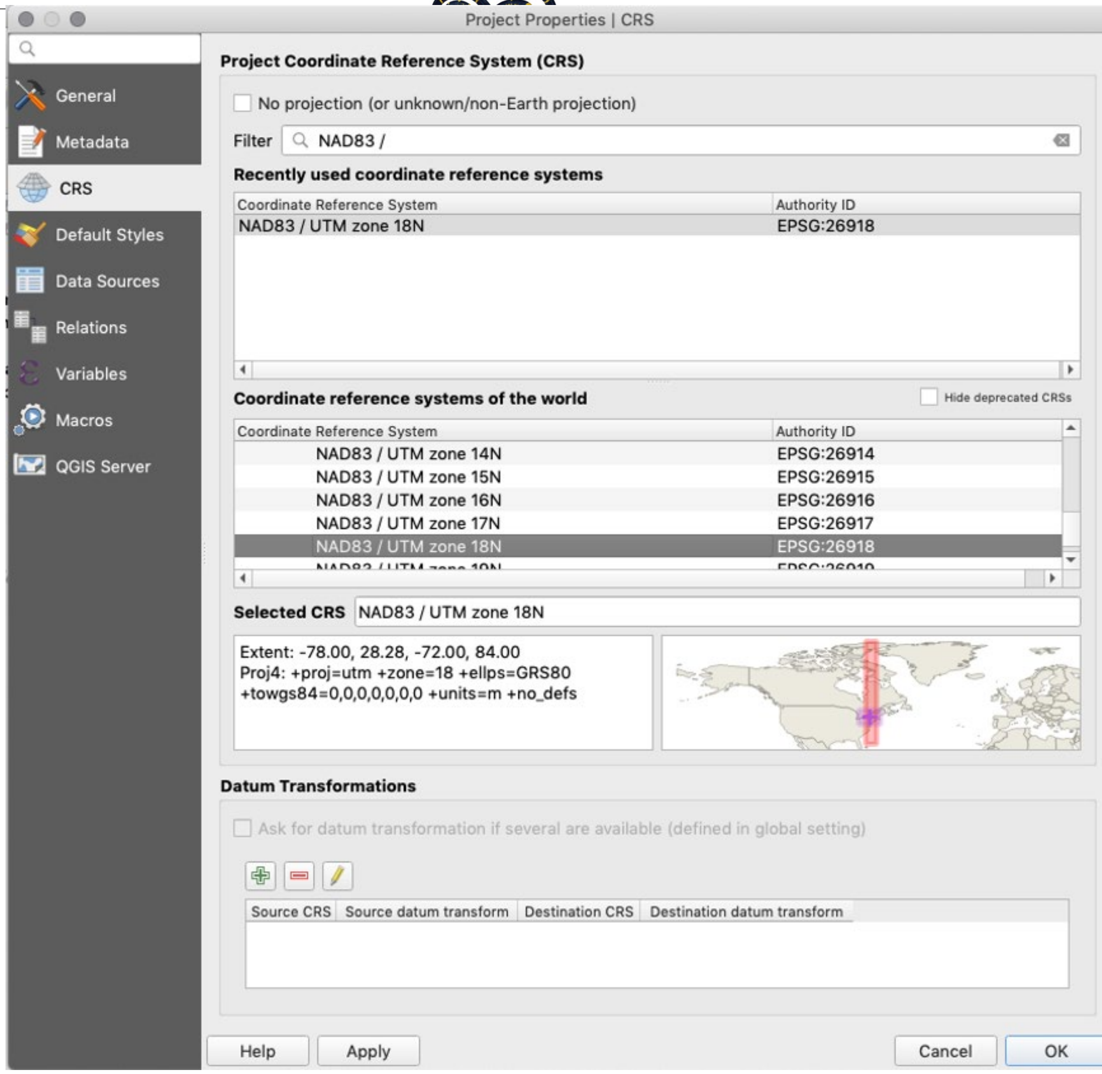
4.3 Analyze the Road Data

We often use latitude and longitude, a 3-dimensional spherical coordinate system, to define the location of points on the Earth (which is an oblate spheroid), but in many cases we transform, or project, these coordinates into a 2-dimensional grid so it is easier to process. QGIS uses a Coordinate Reference System (CRS)[6] to define the coordinate system used for each layer. For cases when you display layers that have a different CRS than the one defined for your QGIS project, those layers will be "projected on the fly" to transform them so they overlay with the other layers in your project. For visualization, on the fly projections are quite helpful, but if you are going to do analyses—like measuring areas or distances between objects—it is better for you to choose an appropriate CRS that preserves spatial qualities such as shape, area, direction, and distance to meet the needs of your project.

In the following steps, you will convert the data into a CRS that preserves area because we will need to measure area in future steps. Because there are many Coordinate Reference Systems to choose from, we will tell you which CRS is best applicable to the data we have in the region we are studying. For more information about CRS, consider reviewing the Coordinate Reference Systems chapter of "A Gentle Introduction to GIS" (docs.qgis.org/3.4/en/docs/gentle_gis_introduction/index.html).

1. First, we will need to convert your project from a spherical model (3-dimensional) to a planar model (2-dimensional). The Universal Transverse Mercator (UTM)[7] projection is a planar model measured in meters, and QGIS will automatically convert the units.

    a. Go to Project > Properties. Navigate to the "CRS" tab in this window. In the "Filter" search field, type "NAD83 /" and then under "Coordinate reference systems of the world," select "NAD83 / UTM zone 18N EPSG:26918" and then click "OK."
    Note: NAD83 / UTM zone 18N stands for the North American Datum 1983 and Universal Transverse Mercator zone 18 North. See the region it covers in the small map on the right of the dialogue box.



Consider: We know that a Treelop is a shy, reclusive creature. What are some characteristics of roads that would make the area around them unsuitable?

For this analysis, we have data for the locations of major roads and can use those data to narrow down our potential survey locations by omitting sub-optimal areas. We chose a 3 km distance from roads because other (fictional) studies on this species showed that the negative effects of roads extended into natural areas up to that distance. **Note**: Although Treelopi are not likely to be near busy roads, they have been observed near these roads (although rarely). If you were doing a similar analysis on your own question, you may similarly find references or expert opinion on what distance threshold to use.

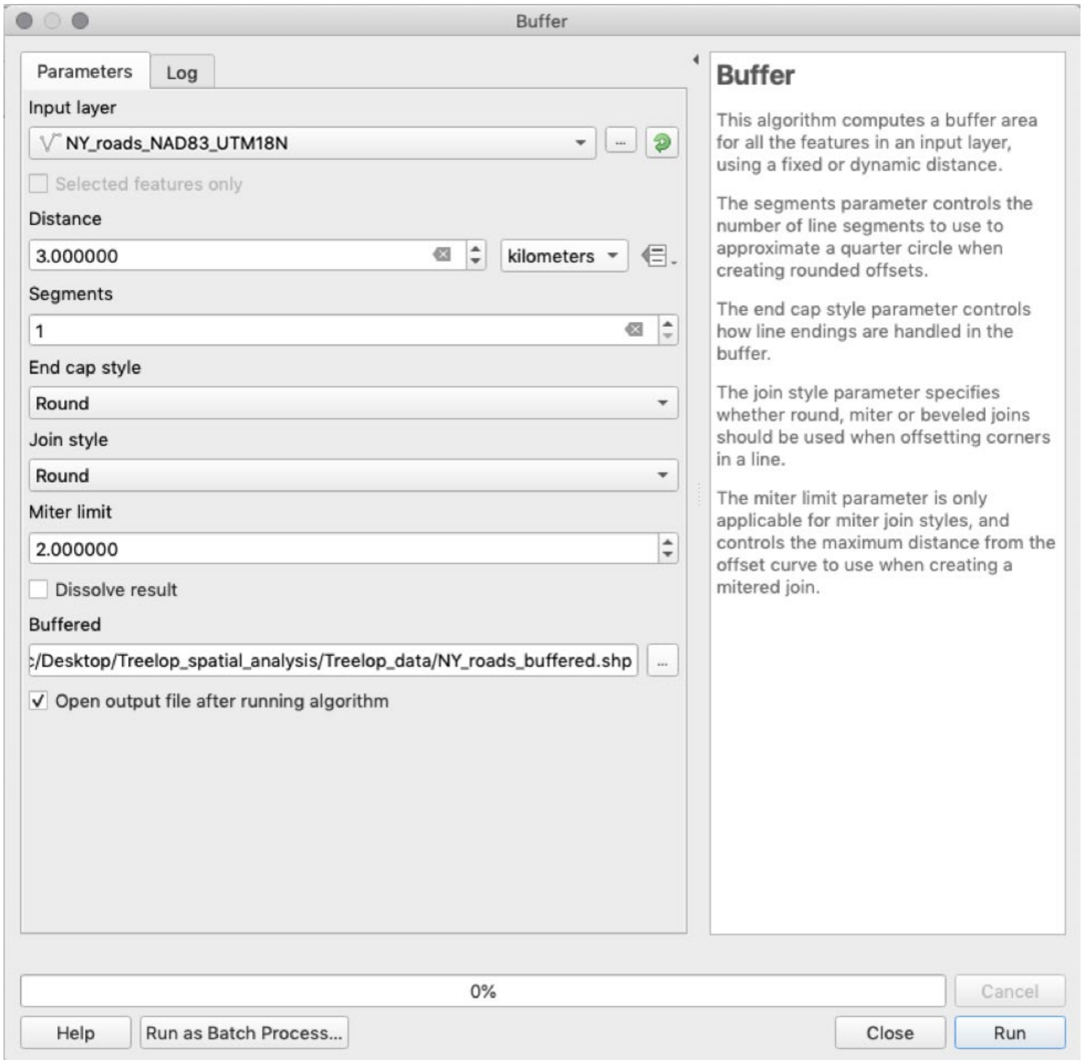
2. In GIS, a common tool to create an area that surrounds a feature (e.g., road) by a certain distance is to create a buffer. To do this for our analysis, we will start by making a new polygon layer showing a 3 km buffer around the roads layer.

   Consider: How is this step different from the previous ones (how is the data different)?

   a. First, because we will be doing analysis that requires measurement of distance in km, we will need to project the "NY_roads" layer to the same CRS that we set to the project before. In the "Toolbox" (Processing > Toolbox), type in "project" and under "Vector general," double-click on "Reproject layer."

Add “NY_roads” as the “Input layer” and the same CRS above (“NAD83 / UTM zone 18N EPSG:26918”) for “Target CRS.” Under “Reprojected,” save this layer as a shapefile named “NY_roads_NAD83_UTM18N” in your working directory. Hit “Run,” and then rename the layer in the Layers panel to match the file name.

b. To buffer the new “NY_roads_NAD83_UTM18N” layer, navigate to Vector > Geoprocessing Tools > Buffer. Read the right sidebar to learn more about the “buffer” function. Select the correct “Input layer,” and under “Distance,” select 3, and make sure the unit next to the distance text box is “kilometers,” Under “Segments,” select 1. Under “Buffered,” save this as a shapefile named “NY_roads_buffered,” hit “Run,” and rename the new layer to match the file name in the Layers panel.



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4.4. Identify the Areas Where the Layers Overlap

1. Take some time to clean up your Layers panel. Drag the “NY_roads_buffered,” “Treelop_preferable_landcover,” and “NY_bio_1_suitable_polygon_valid” to the top of the Layers panel.

We now have our discrete data layers, each adapted to reflect where Treelopi might appear or not based on what we know about their behavior and needs. Our next step in our analysis, then, would be to see how all of these data combined can help us create a map of potential hotspots where Treelopi might be found: areas of New York

State that have suitable temperature, adequate land cover types, and are far enough from roads. For each of the steps below, be sure to read the description of the tool, which will appear on the right side panel within the dialogue box.

2. Calculate the intersection between the suitable land cover and suitable temperatures. Go to Vector > Geoprocessing Tools > Intersection. As the "Input layer," use the vector of suitable temperature ("NY_bio_1_suitable_polygon_valid"), and set the "Overlay layer" as preferable land cover ("Treelop_preferable_landcover"). Under "Intersection," select your working directory and save as a shapefile named "LC_temp_intersection." Click "Save" and then click "Run."

   Close the dialogue box and rename the "Intersection" layer to match the file name.

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3. Remove areas near roads using the "Difference" tool. Go to Vector > Geoprocessing Tools > Difference. Use the "LC_temp_intersection" layer as the "Input layer," and use the "NY_roads_buffered" as the "Overlay layer." Under "Difference," save as a shapefile named "LC_temp_roads_difference" in your working directory. Remember to rename the layer in the Layers panel.

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If you look at the Attribute Table of this layer, you'll notice that all of the original landscape geometries remain. We are interested in the total suitable area in New York State, so we need to dissolve these geometries into one. Go to Vector > Geoprocessing Tools > Dissolve. Read the right sidebar to learn more about the "dissolve" function. Use the most recent layer ("LC_temp_roads_difference") as the "Input layer." Under "Dissolved," save this layer as a shapefile "Treelop_habitat_NY" in the working directory. Click "Save" and then click "Run." This process will take a few minutes. Once complete, rename the layer and check the Attribute Table; there should only be one row. Please note that the attribute table for this output will show data from the first row only and does not represent the attributes of the layer anymore.

4. Your instructor may ask you to take a screenshot of the map of your "Dissolved" Layer (all other layers not selected) or to make a printable map (one with a title, scale bar, legend, compass arrow, data source, author, date, etc.). These steps are not included here but may be provided by your instructor.

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PART 5: APPLY YOUR UNDERSTANDING OF THE RESULTS TO A CONSERVATION QUESTION

5.1 Consider Your Results and the Data

You have completed a preliminary map from your analysis. Congratulations! Now, let's think through what this map means for your assignment to prioritize where the small non-profit conservation organization should survey for Treelopi in New York State.

- If the organization was going to survey all of the land on this map, how many square kilometers would they have to survey?

  To calculate the area of habitable land in New York State, open the Attribute Table of "Treelop_habitat_NY." Click on the "Toggle editing mode" to make the layer editable. Then, click "Open field calculator." Create a new field with "Output field name" as "area_sqkm." The expression for calculating the area of every row in an attribute table is simple: under the Search text box, select Geometry-> $area. However, this will calculate the area in map units. Since we are using the Universal Transverse Mercator projection, the units are currently in meters. Since we want kilometers, we need to multiply the area by 0.000001. This will show the total area (in km^2) of habitable land in New York State that is suitable for Treelopi.

- What is the total area of our estimated "optimal" habitable land for Treelopi?

- Examine the results of your analysis (i.e., map and calculated area). What do you think some limitations would be for surveying for Treelopi?

- Given these limitaitons, would you feel comfortable recommending a priority area to survey? Why or why not?

- What do you think are some ways to further narrow down priority areas for surveys? Go back to your response to Question 1. Were there data types listed there that might help you? What else would you like to know that could alter your priority areas for surveys?

- Based on the assumption that all of the habitat on your map is suitable and your understanding that this species is considered rare, do you think that Treelopi are limited by suitable habitat? Hypothesize what else might be limiting their numbers.

- A brand-new study is published on Treelopi. The results suggest that Treelopi need large contiguous habitat (at least 20 sq km) for breeding. How can we use this new information to better understand their suitable habitats? Explain how you might further refine your map through spatial analysis to incorporate this information. (Do not list step by step instructions of how you would accomplish this with the software rather a summary of what those steps would accomplish.)

- Have you considered the limitations of the provided data? Let's review the data listed in Table 1.

  Political boundaries are mainly stable and because we are focused on New York State, this data doesn't appear to have a limitation but rather defines our scope.

  Temperature data in this exercise is only provided as mean annual temperature. How might mean annual temperature mask variation in temperatures throughout the year? What other measures of temperature (or other climate variables) might be important? Why?

  If you navigated to the source of the data (worldclim.org), you'd see that the mean annual temperature is calculated from a 30-year period (from 1970–2000). What might have changed since then? (**Note**: averages for climate data are normally obtained by looking at a 30-year interval of years.)

  Likewise, if you look at the metadata associated with the land use/land cover dataset, you'd notice that it is from 1990. How might things have changed in the past ~30 years? How could updated data source help narrow down your survey area? (**Note**: up to date data layers may or may not be available. Sometimes more recent data are only available after a fee is paid. Depending on your project needs and budget, it might be worthwhile to spend money on more up to date datasets.)

  Roads data is updated to 2018, but only contains Interstates, State, and Federal roads. If you thought that Treelopi were averse to all types of roads, you might want to find a data source that included county, town, and private roads.

Treelopi sightings data has no metadata associated with it. Unfortunately, it is common that some data sources will not provide helpful information beyond the spatial information (e.g., only GPS coordinates). What sort of data do you wish you knew about these sightings? How would it be helpful for supporting your analysis and recommendations?

5.2 Reporting Back to the Conservation Organization

Based on your work and responses above, write out a brief overview of what you did to get the preliminary map (don't list steps, rather summarize the final output). Explain your recommendation for where to do surveys, and/or what other steps should happen before a final survey recommendation is set.

GLOSSARY

Glossary terms are derived from: QGIS Development Team. 2019. QGIS Geographic Information System. Open Source Geospatial Foundation Project qgis.osgeo.org. See "A Gentle Introduction to GIS" docs.qgis.org/3.4/en/docs/gentle_gis_introduction/ for more helpful background information.

1. **Vector**: a type of spatial data made up of vertices and paths which uses geometry to represent real-world features in GIS. Vector data are presented as points, lines, and polygons (areas).
2. **Raster**: a type of spatial data made up of grids of pixels (cells), often used for data that is continuous across an area and cannot easily be divided into vector features, e.g., the backdrop behind vector data.
3. **Geometries**: points, lines, and polygons that represent a spatial feature.
4. **Expression**: a way to manipulate attribute value, geometry, and variables in QGIS to perform functions like changing the geometry style, the position of the label, the height of a layout item, etc.
5. **Polygon**: a closed-shape vector object defined by X and Y coordinate pairs.
6. **Coordinate Reference System (CRS)**: uses coordinates to define how a two-dimensional GIS map is related to real places on the three-dimensional earth. Deciding on which map projection and CRS to use depends on many factors, including the regional extent of the area you want to work in, the analysis you want to do, and the availability of data.
7. **Universal Transverse Mercator (UTM)**: a global map projection which assigns coordinates to locations on the surface of the Earth. The UTM CRS divides the globe into 60 equal zones (numbered 1 to 60) starting at the international date line. Each 6 degrees wide in longitude. Each zone is further divided into zones north and south of the equator.