

6-7. Connectivity variables.

If you're a frog, wetland and forest area may be important for you, but a wetland 4 km away is almost certainly not as useful as a wetland closer by. The concept of connectivity combines both the distance and the area of required habitats in the landscape into a single metric. Researchers have proposed a number of different approaches for calculating connectivity.

For amphibians, calculating connectivity can be particularly tricky because they may require both wetlands and upland habitats (e.g. forest, scrubland) during different times of the year. In addition, amphibians are usually difficult to find in their upland habitats, so their breeding site preferences are usually much better understood than their terrestrial habitat preferences.

We'll calculate two metrics for the connectivity of each NAAMP stop within the landscape – one that considers only wetlands and the other that considers both wetlands and nearby upland habitats. Comparing the performance of these two in explaining frog presence/absence and species richness will allow us to determine the extent to which knowing upland habitat area is necessary for predicting frog distributions.

The approach to connectivity that we'll be using is called the Incidence Function Model (IFM) approach (see Hanski 1999). It is based on a metapopulation model in which organisms are moving between habitats and their ability to find a given habitat depends on their dispersal ability, the size of the habitat, and how far the habitat is from the organism. Mathematically, connectivity in the IFM is defined as:

$\sum (e^{(-\alpha * \text{distance})} * \text{area}^{0.5})$, summed across each habitat within the buffer.

Ignoring the exact mathematics, you should be able to see that habitat contributes more to the total when it is less isolated (i.e. distance is low) and when it is larger. In the equation, α is defined as $1/(\text{mean dispersal distance})$ for the species. We'll be digging into the research literature as the project progresses to get low, medium, and high values for this that we can use with the individual species.

For the first connectivity metric, CONNECT_WET, this equation will consider only the distance to and area of nearby wetlands. For CONNECT_TOTAL, this equation will consider the distance to nearby wetlands and the area of each wetland plus the area of undeveloped upland habitat within 600 m of each wetland. We chose 600 m because studies of amphibians in eastern and central North America find >90% of individuals within 600 m of a wetland.

We'll first show you how to calculate CONNECT_WET using qGIS and then excel. There are a lot of steps, but it's really all just a matter of getting the distance to each wetland as well as the area of each wetland. Because the NWI wetland layer breaks single large wetlands (e.g. Rivers) into multiple smaller polygons there are some added steps required to combine adjacent wetlands that are the same wetland type. If you were to leave a river (for example) as a bunch of small riverine wetlands, you would get a different value for connectivity than if you combined them all to make a single river (which they in fact are).

The other complication is that we want the distance from the NAAMP stop to the nearest point on a given wetland, not to the center of each wetland. To get this, we have convert each wetland polygon to a set of nodes (i.e. points) that define its perimeter and then find the node within each wetland that is closest to the NAAMP stop. qGIS and excel will carry out all these steps for us, but yes, there are a bunch of steps. The best news, though, is that because the connectivity measurement weights the wetlands by their distance from the NAAMP stop, we only have to calculate each connectivity measurement once for each site. There's no need to do it at every scale (since the outlying wetlands will barely contribute anyway).

OK, so we'll assume you have your project (e.g. 270408) open with all your layers assembled. Most people will likely choose to calculate connectivity last, though there's no reason you have to do this. However, this protocol will assume that you already know how to do things like make clips and do calculations within attribute tables.

STEP 1: Make a clip of all wetlands within 10000 m (note: you may already have done this).

In the Vector menu go to Geoprocessing Tools, then Clip
For the Input vector layer, use nwi. For the clip layer, use buff10000 (or the 10000 m buffer that you previously created). For the Output shapefile, click on Browse and then type in "nwi-clip"

STEP 2: Dissolve wetland boundaries for adjacent wetlands of the same type (since these are usually part of the same wetland even though NWI breaks them into pieces).

In the Vector menu go to Geoprocessing Tools then Dissolve
For the Input vector layer, use the nwi-clip (i.e. the 10km wetland clip)
For Dissolve field use WETLAND_TY (this is wetland type, abbreviated in qGIS)
For the Output shapefile, click on Browse and use the name "nwi-dissolved"
(Note: This process might take a couple of minutes if there are a lot of wetlands.) When prompted, add the new layer to the TOC

If you're brave and you want to look at the attribute table for nwi-dissolved, you'll note that it now just shows one wetland of each type (6 total for 270408, compared with 724 wetlands in the original clip). If you're not brave, don't worry about this.

STEP 3: Separate the wetlands back out again (adjacent wetlands should now be combined but non-adjacent wetlands will get pulled back out on their own again).

In the Vector menu, click on Geometry Tools then Multipart to Singleparts
For Input vector layer use nwi-dissolved
For Output shapefile, use nwi-multi
Add this layer to the TOC

If you look at the attribute table now, you'll see 511 wetlands, so a few more than 200 were combined from the original clip. If you look more closely (not required) you'll notice that

the built in shape area has just been copied down the column for each wetland type. These are not correct of course, which is why we'll calculate area again further on.

STEP 4. Give each wetland an ID. This is necessary so that when we convert wetland polygons to nodes (points), we can keep track of which wetland each nodes came from.

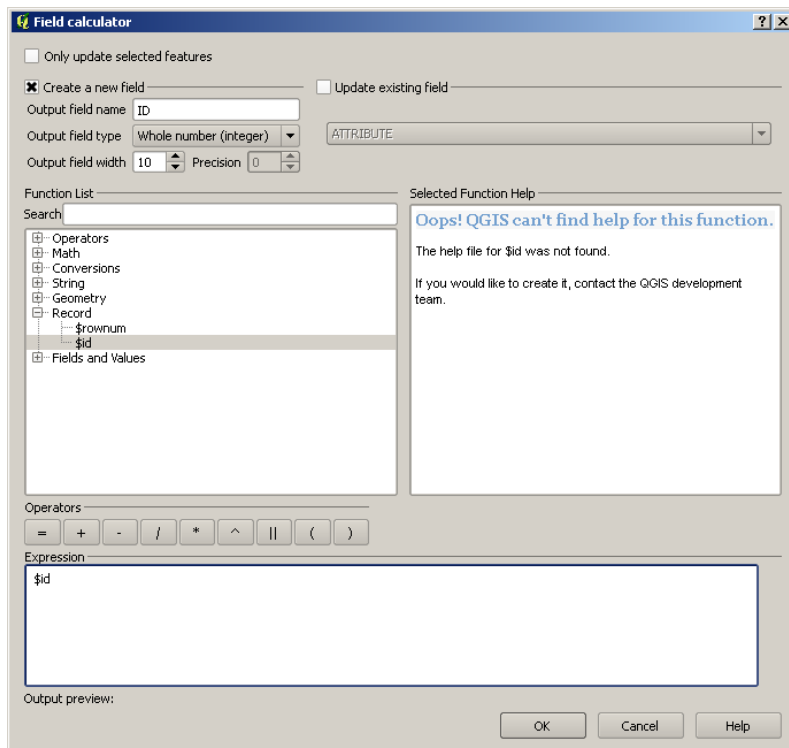
Open the nwi-multi attribute table

Click on the pen, then open the field calculator

Create new field called "ID". You can keep the field type as Whole number (integer)

Click on Record, then \$id, then click OK (see below)

When you're done, the wetlands should each have numbers down the row.



STEP 5. Calculate the area for each wetland. These need to be recalculated after all the dissolving and then separating.

On the nwi-multi attribute table, open field calculator again

For output field name, use "area," and for field type, use Decimal number, with Precision=1.

Then click on Geometry and then \$area

When you click OK, you should have an area column. Now click the pen again to SAVE YOUR CHANGES.

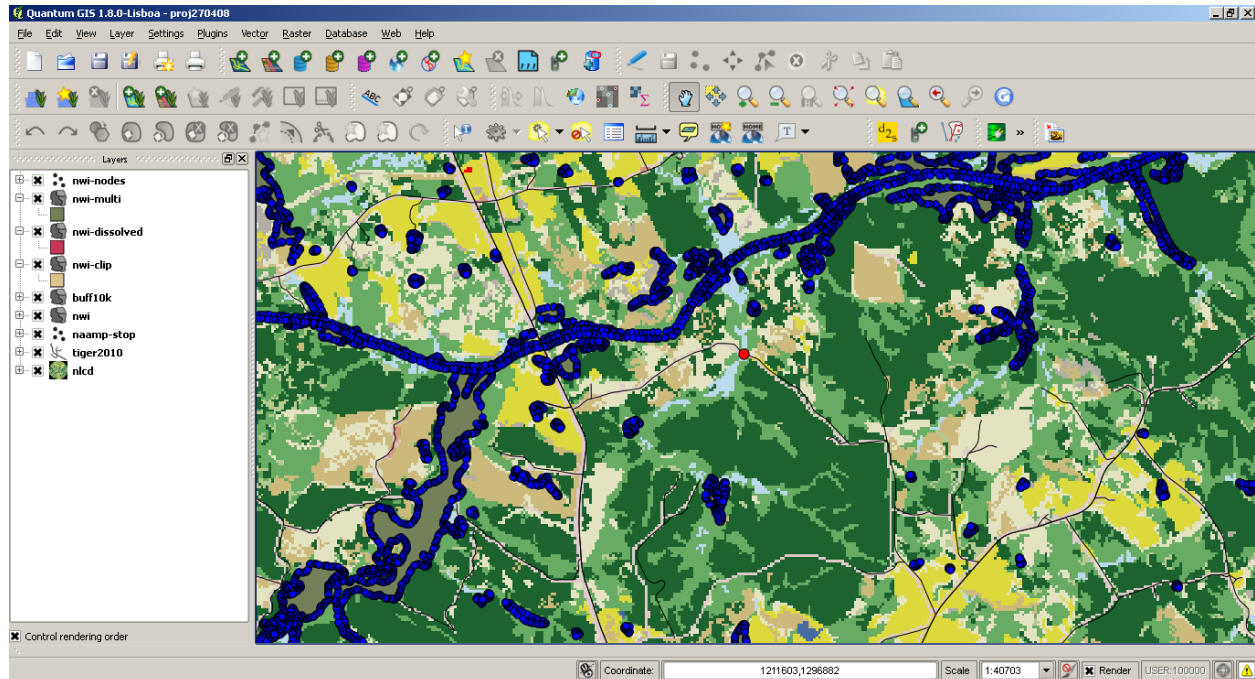
STEP 6. Create nodes outlining each wetland. Again, this is necessary to estimate the distance to the nearest point on each wetland.

Go to the Vector menu then Geometry Tools then Extract Nodes

For Input line or polygon vector layer, use nwi-multi

For Output point shapefile, use nwi-nodes
Add the new layer to the TOC

You can see on your map that each wetland has been converted into a bunch of point. So the last set of steps is to calculate the distance to each of the points and find the minimum distance for each wetland.



STEP 7. Determine distance from the NAAMP stop to each node and output the result as a csv file.

Go to Vector then Analysis Tools then Distance matrix

For Input point layer, use nwi-nodes

For Input unique ID field, use ID

For Target point layer, use naamp-stop

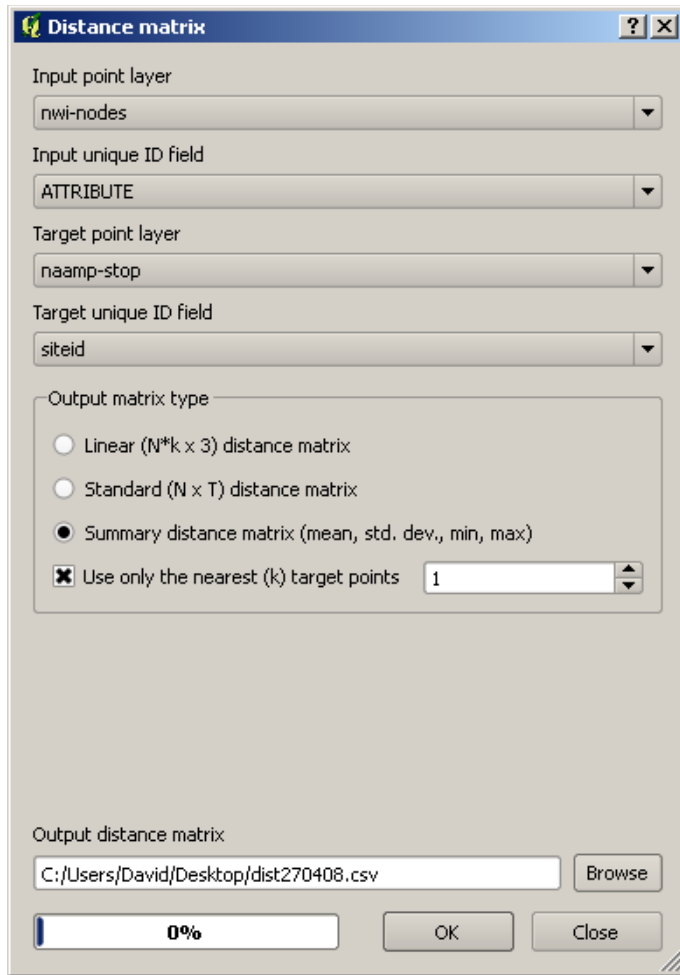
For Target unique ID field, use siteid

For Output matrix type, use Summary distance matrix

Check the box below this to use only the nearest (k) target points: (1)

For Output distance matrix: use, for example, dist270408 for the name

(Note: the computer might look like it's frozen during this process since the progress bar doesn't move, but it is creating the file)



STEP 8. Output the wetland area information

(Note: This requires the MMQGIS plug-in, so install that if it's not installed already. You should have used it previously in the road length calculation.)

In the Plugins menu, click on mmqgis, then Transfer then Attributes Export to CSV file

For Source layer, use nwi-multi

For Attributes, select ID and area

Click Browse and then change the Output CSV file to area270408 (or whatever route you're analyzing)

OK, you should now have 2 csv files – one with area and one with distance from the naamp stop (to each node). We'll combine these in excel. Since the menus and commands for excel differ between Windows and mac, we've given separate instructions for the two environments for STEP 9..

MAC COMMANDS

STEP 9. Determine the shortest distance from the stop to each wetland

Open the dist270408.csv or analogous file in Excel

From the Data menu, select Pivot table

In the Pivot table builder pop-up:

For Row labels use Input ID

For Values use min of MIN (note: this will give the minimum distance for each wetland ID)

You should now have a table with each wetland ID and its corresponding minimum distance

PC COMMANDS.

STEP 9. Determine the shortest distance from the stop to each wetland

Open the dist270408.csv or analogous file in Excel

Click on Insert, then Pivot Table (all the way at the left)

Highlight all the data columns (A-E) to select the range

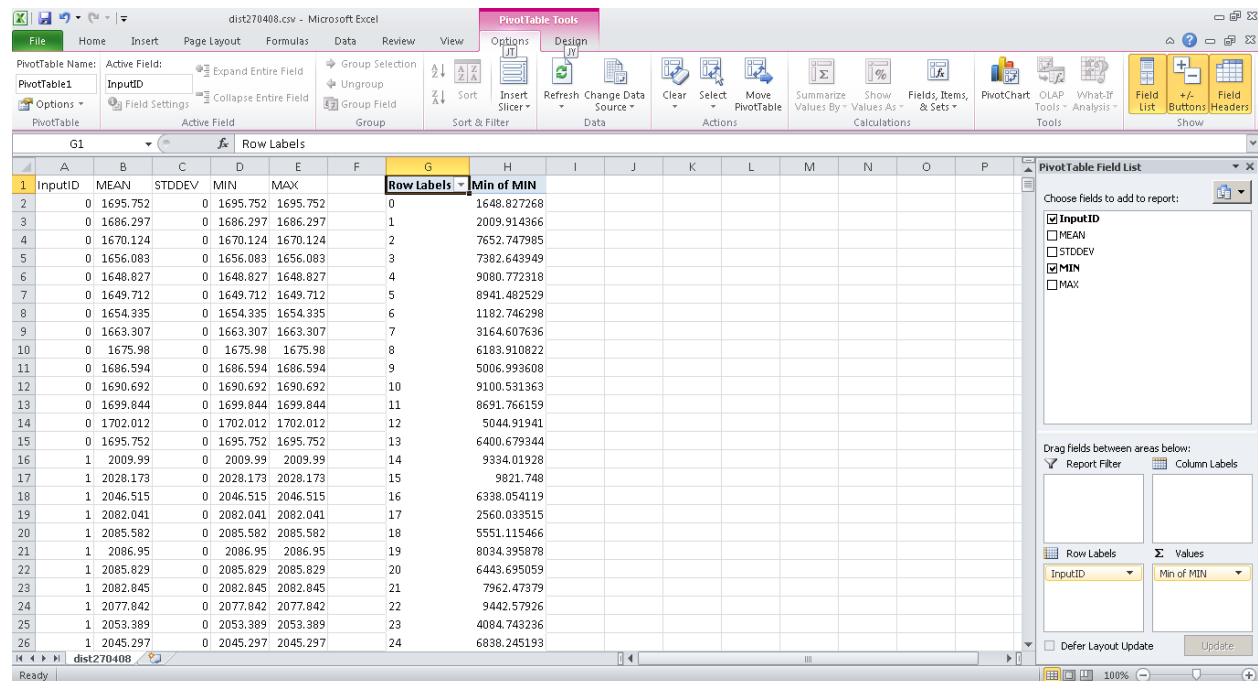
In the Pivot Table Field List on the right, drag InputID into the Row Labels box

Then drag MIN into the Values box

The default is to produce the “Count of MIN” we want the minimum value though, so...

Click on the down arrow next to “Count of MIN” in the Values Box

Go to Value Field Settings and click “Min” so that “Min of MIN” appears as the name



STEP 10 (mac or PC). Combine the area and distance files together

Open up the csv file with the area information in it (e.g. area270408)

Cut and paste the two columns from the pivot table (Row Labels and Min of MIN) next to the area column. Do not include the bottom two rows ("blank" and "Grand Total"), we just need the distances for each wetland.

Label the new columns (C and D) ID2 and dist. ID2 should be duplicated from the nodes worksheet, but pasting it in anyway will allow you to make sure that all the wetland numbers match up.

REALLY IMPORTANT NOTE – YOU SHOULD MAKE SURE TO SAVE THIS SPREADSHEET (THE ONE WITH DISTANCE AND AREA OF EACH WETLAND) WHERE YOU CAN FIND IT LATER ON. THE INSTRUCTIONS BELOW SHOW YOU HOW TO COMPLETE THE CONNECTIVITY CALCULATIONS WITH HYPOTHETICAL DATA FOR FROG MOVEMENT DISTANCE, BUT WE’LL NEED TO SUBSTITUTE IN ACTUAL MOVEMENT DISTANCES LATER ON.

STEP 11. Calculating each wetland’s contribution to connectivity.

Recall the formula for connectivity: $\sum (e^{-\alpha * \text{distance}} * \text{area}^{0.5})$

We’ll hopefully have some real data to estimate α (1/mean dispersal distance) later on. For now, let’s use $1/200 \text{ m} = 0.005$, which would end up being maybe low-end to average dispersal. So for each wetland we want to take: $e^{(-0.005 * \text{distance})} * \text{area}^{(0.5)}$

In excel, we can just create a new column (column E) called wet_connect and then enter in this formula. In cell E2 (just below the column title), we can type: “=EXP(-0.005*D2)*SQRT(B2)”, where D2 contains the first row of distances and B2 contains the first row of area values. Then click the check box to get the calculation.

Now, copy this cell and paste it all the way down the column. This should apply the formula to all of the cells. Once, you’ve done this, feel free to scroll down the column to look at the values. Most of them are extremely small (e.g. E-10 or E-20). Basically, if a wetland is too far away, it makes almost no contribution to connectivity. If the mean dispersal of a from is 200 m, it doesn’t really matter what’s 7 or 8 km away.

STEP 12. Summing up the wetland connectivities.

Connectivity for this site is just the sum of all the individual contributions. So we just need to add them down the column. Use the sum function in Excel to sum up column E. For the demo site 270408, I get 34.7 for CONNECT_WET. When you sum, you might notice that the last wetland (510) accounts for more than half of the total (i.e. 18.99). This is the big river that runs by the NAAMP site, and if you look back at the map of the site, it’s intuitive (at least to me) that this wetland should be a very big contributor to connectivity.

