Connectivity for Climate Change: Assessing Threats and Identifying Conservation Actions

John Ossanna: Welcome from the US Fish and Wildlife Services National Conservation Training Center in Shepherdstown, West Virginia. My name is John Ossanna. I'd like to welcome you to our webinar series held in partnership with the US Geological Survey's National Climate Adaptation Science Center.

Today's webinar is titled, "Connectivity for Climate Change -- Assessing Threats and Identifying Conservation Actions for Three Wildlife Species in the Southeast United States." We're excited to have Jen Costanza from North Carolina State University with us today.

Let's get started. To introduce Jen Costanza, we have Shawn Carter with USGS, who will be introducing her. Sean, take it over.

Shawn Carter: Thanks, John. It's my privilege to introduce Jen Costanza today to be our speaker. Dr. Costanza is a research assistant professor in the Department of Forestry and Environmental Resources at NC State. Her research seeks to better understand recent and potential future threats to ecosystems and landscapes.

The threats she studies include direct and indirect effects of climate change, land use, and altered disturbance regimes. She used assimilation models to project future landscape change, in addition to a variety of quantitative and qualitative methods, for her research.

She works to produce a body of knowledge that can be used by natural resource and conservation practitioners and to make better management and policy decisions. I've had the privilege of working with Jen in the past. It's a privilege to have her, speak with her, today about some of her work. Jen, welcome. Please take it away.

Jennifer Costanza: Thanks. Hope you all can hear me. Yes, thanks for the introduction, Shawn, and thanks to Elda and John for inviting me and getting this set up.

Today I'm going to talk about some work we've done on connectivity in the Southeast, specifically with climate change in mind. Even more specifically, thinking about once we have identified a connectivity network or species, what do we do? How do we figure out what to do for climate change with that network?

First, I want to take a quick step back and thank my collaborator. This is part of a bigger or multi-part project that's had some funding from the Southeast Climate Adaptation Science Center. It involves a number of collaborators at NC State and beyond, and here they are.

They've done bits and pieces of it. It's been a really fun team to work with. We're talking about connectivity. Many of you all participating on this webinar may have heard a lot about connectivity or may not have.

The idea has gained traction in the recent past, especially with climate change in mind. This paper from 2009 is almost 10 years ago now, but it really underscores that point. This review by Heller and Zavaleta cited that increasing connectivity was the most frequently proposed management strategy in the literature.

They reviewed the literature and found that this was the number-one strategy for management of wildlife and biodiversity for climate change. Being 10 years ago, that helped stress connectivity into the limelight over the last several years in folks working on connectivity with climate change in mind as a climate change adaptation strategy.

In my mind, those studies that have aimed to map and plan for connectivity have taken one of the leaps in two different directions. Maybe there's more directions than this. I have a problem with my titles on this slide, but the study by Nuñez et al in conservation biology is one example of the types of studies that have looked at connectivity of climate itself.

The study looked at "How can we connect gradients of temperature?" or in other cases there's other climate variables. "How can we make connections with climate explicitly in mind because we think that species will need to move and migrate to track changing climate?"

Then the other set of studies are illustrated with the right two pictures here on the screen, really have in mind the fact that connectivity in and of itself is important because a network of connected habitat can support large, genetically diverse populations. That can enhance the capacity of species to adapt to a number of changes, including climate change. Connectivity in and of itself is important for robust populations and species.

Our study has taken the latter tact in that we were identifying some existing connectivity networks, but we then wanted to think about, what do we do once we've identified these connectivity networks for a species, what do we do for climate change?

Next slide. Our broader study focused on mapping and modeling connectivity for three species in the Southeast. They're identified as priority species and we consulted with biologists and experts in the landscape conservation cooperatives in the region and others.

All three of these species use bottomland hardwood habitat to some extent, but they vary in the degree to which they're specialists or generalists and the home range or habitat sizes that they use.

The snake here is the timber rattlesnake. I'll refer to it just as the snake. It's got perhaps the smallest home range and it has smaller movements and dispersal distances. It's just somewhat a specialist but will use some upland habitat in addition to the bottomland hardwood habitat.

The bat here is Rafinesque’s bigger bat. It has a little bit larger home range and dispersal distance and it's probably the most specialist in bottom-line hardwoods throughout the region.

Then the bear is the black bear. It has the largest home range and dispersal distances. It's the most generalist species, general use, just general forest cover, even some ag land sometimes.

Those are the three species we were working with. I'll just mention too that the broader goal of our team was to model and map how landscapes can be connected across the region for those three species.

Then we sought to look at the priority actions and priority conservation actions for conserving those linkages under climate change. Our prior work focused quite a bit, and I'm not going to talk about a lot of it here, but focused quite a bit about the technical aspects of how to map connectivity.

We used a number of different tools and input data to do that. My collaborators have some nice work on that. Again, but for this talk I'm going to really talk about, once we have the maps of those linkages, what do we do with them for climate change?

This slide is just a overview of where we started from. What's the connectivity mapping? A common approach with mapping connectivity networks is to input some kind of surface or data related to the resistance of the environment to movement.

In our case, we mapped habitat suitability based on climate and land use, land cover, and then took the inverse of it to construct our resistance surface. We used, just briefly, an ensemble of environmental niche models and climate data from 30 years in the recent past from the Prism dataset.

We did this for every species. I'm showing black bear but we did this for all three species. Then we identified habitat nodes, which were the top third of grid stalls in terms of their being the highest suitability in the region.

Then from those top third we selected patches, cells that made up patches that were at least 20 times the mean female home range size for the species. We wanted big patches of suitable habitat for nodes.

Then the work I'm showing now is the result of the...we used Linkage Mapper software to map least-crossed paths between pairs of those nodes in the landscape. Then we buffered them to five kilometers. That's the example map you're seeing here for the black bear.

Then this is just what this looked like for all three species. That's where we were starting from with maps of linkages. Again, we wanted to then think about, once we have this map of linkages that's based on the current habit/current climate, what do we do for climate change? For us, we started with looking at the literature. The way we started thinking about this came firstly from the idea of climate refugia.

This is a picture from Morelli et al in "PLOS One" a couple years ago. Firstly, what we do for climate change with these linkages depends on their threat. The climate change refugia literature points out that refugia are areas where suitable climatic conditions will persist.

Even though there's changes at regional and global scales, there are places locally in the landscape where suitable habitat will persist. In our cases in the linkages, that might be more stable over time in terms of their suitable habitat, those might point to places where we don't have to consider climate change as a threat, but we need to manage other non-climate threats as a priority in those.

This is the first cut. Then in converse places, the linkages that would change a lot where the climates are at a tie, where suitability might decrease a lot over time and be expected to decrease over time, might be places that require adaptation.

Here's just one example of a picture related to population migration, assisted migration. Within an existing population they might think about movement of the linkage or movement of the population to different places. Places where you'd want to do that, you'd want to know in this case what the condition is of the surrounding landscape.

Again, that points to non-climate stressors. Even though you're concerned about climate change, there might be other non-climate stressors that you might want to take into account if you're going think about moving a linkage, moving a species' habitat, or establishing a population in a different place.

Thinking about that dichotomy between climate change refugia and places that need adaptation led us to a relatively simple framework that I'm going to show you that we applied for the R3 species. Again, it's a degree of climate change threat plus non-climate stressors. In this case we focused on the expected degree of land use change and the level of protection for conservation management.

We focused on land use change in particular, especially in the Southeast. Growth of urban areas has been shown to be one of the key types of land use we'll see in the future. Also, land use and climate change can have interacting effects. Land use change is important to think about.

Then finally, the final bullet there is that we also thought about we need to take into account the importance of each linkage to the overall network. Even if the linkage is severely threatened by climate change, if it's not as important to the overall habitat network or to the species population and the resilience of the species, then it may not be worth focusing on.

Those are the things we thought about in developing this framework. Again, we're talking about linkages in an existing connectivity network. We can think about climate change threat from low to high or a dichotomy from low to high. Again, with low climate change threat, places of low threat being places of refugia and high threat in places where adaptation is needed.

For those refugial linkages, we think about degree of land use change and degree of protection onto two axes. That might lead to a space in which we have a number of conservation priority actions that we might take. Here I'm just dividing low and high for each of those axes. You could divide it more.

We chose to keep it simple in thinking about the types of actions or priorities that you might think about. These are just examples of things that might be priorities in the linkages based on their low climate change threat and then based on their degree of protection and degree of land use change.

For example, if the degree of land use change is high and the existing protection for conservation is low, which is that darkest blue, then adding protection might be a priority if you think about trying to add protection before land use change becomes an issue or before it becomes as drastic. If land use change in the future was expected to be low, that might be all right.

The priority might be to work with individual landowners. In this case, I had written "private landowners," but I really mean individual non-conservation landowners. Those are some of the things we've talked about or we thought about for refugia.

Then places that need adaption, you could divide up the same axes. These are higher climate threat, but you have some parallel here.

This is the typology of priority actions for the linkages that need adaptation. These focused around moving protected areas or moving corridors within a projected area. In an extreme case of high climate threat and high anticipated land use change and low protection, maybe it's worth moving populations to a more connected portion of their range.

Again, these are just suggestions but a first cut of how to think about and prioritize some actions. Also, again we're assuming that the most important linkages have been identified in each network. This is how we apply this framework to our three focal species. We calculated the degree of climate-change threat by the middle of the 21st century for all linkages.

Then narrowed it down to the most important linkages in the network and used the two additional criteria, the degree of land use change expected and the degree of protection, to help determine the conservation priorities. Then we did some work to look at the geographic patterns and how those aligned among species. I'll show you those.

I already showed how we use environmental niche models to develop the suitability or resistance surface for the original connectivity network. To calculate our index of climate change threat, we looked at the change in suitability.

We did the same thing. The same modeling approach but for future climate, and we used, again, an ensemble of niche modeling and also an ensemble of future climate projections for the A2 scenario, which is a relatively high-emission scenario. We didn't change land cover here, so it's using existing land cover but it's using future climate.

I want to emphasize here, our climate change threat here is a measure of not just the absolute change in climate but it's on a relative basis to the species. It's relative to habitat suitability. If you're familiar with the vulnerability framework, it's not just the climate change exposure but it's also the sensitivity of the species to that change, or the species habitat to that change.

Then we overlaid our linkages and we calculated a mean value, average value, of all the pixels falling in each linkage. Then we also compared it to a regional average, which I'll get to in a minute.

Here's the distribution. Here is the box plots by species. This is just showing the distribution for all linkages for each species, the percent change in suitability. The dark black bar in the middle of each box is the average change across all the linkages for the species.

Then that box, the high and low end of that rectangular box is the 25th and 75th percentiles, and the whiskers represent more the tails of the range.

This points out that for all species on average, the suitability decreased. This is within all the linkages. The suitability decreased. The bat saw the most decrease, about 32 percent decrease in suitability, on average, in the linkages. The bear had the least decrease, about 15 percent, and then the snake, in between at 23.

What I think is actually more interesting. In order to divide up our linkages into that dichotomy of a low and a high threat and really to relate this to a climate refugia idea, we wanted to look at linkages that were more stable in climate and more stable in their suitability in this case than the surrounding landscape.

We took the region-wide average, so all pixels in the region, and compared each linkage to that average by species. Interestingly, the bat did worst in terms of overall decrease in suitability and also does the worst compared to its regional average, which was about 11 percent. On average, the linkages had about three times worse change in suitability compared to the landscape as a whole.

The snake actually had a moderate decrease on average in those linkages but actually did better than its regional average of 28 percent. The snake's linkages had 23 percent decrease in the region-wide average was slightly worse than that.

If we look on average for the snake, linkages on average were climate refugia, if we're defining them as doing better than the regional average of change. At least they have a somewhat lower threat of climate.

When we look at a map, we can divide up the linkages again based on the larger decrease or below the region average or a smaller decrease or any increase in their suitability. We look across all three species.

We can see, again, there are many more linkages for the snakes that are blue. That means they were relative refugia or did better than the region average, and for the bat especially and somewhat for the bear there were quite a few that had a large decrease in suitability.

We're still talking about all linkages. Now I'm going to show how we put all these things together to get towards that framework to be applied. First we wanted to prioritize important linkages.

There are a number of ways we could have done this. We chose to use a graph theory metric called the change in integral index of connectivity, or DIIC, which basically measures the change in the total habitat connectivity, or the total networks connectivity with each linkage being removed.

We selected linkages that themselves were important based on that metric, or that connected to the top 10 percent of important nodes. We selected the top 10 percent of important nodes with that same criterion. If the linkage was important or connected to one of those important nodes, we called it important in our network.

For our metric of land use change, we overlaid projected urbanization in the Southeast. This, again, is one of the biggest types of land use change in the region. We felt it was very important to include.

We needed a threshold of low versus high in our framework of low versus high land use change. We defined lower-than-average urbanization rate by the middle of the 21st century as being lower than the regional average for the study area, which was 139 percent increase.

If it had less than 139 percent increase across the linkage, then it was a low rate of urbanization within that linkage. Similarly, for protected areas, we want to know the degree of protection or proportion of each linkage that was protected.

Regionally, about 10 percent of the region is under some conservation protection. A measure higher than that had a high level of protection, and lower had a low level of protection.

Putting that all together, we can start looking at this. Once we whittle it down to just the most important linkages, which I'll show maps in a bit, we can start looking at low versus high climate change threat.

These are for each species. Each pair of bars is a species and the low and high are low climate change threat, lower than the average for the species, and higher. Again, in parallel with that box plot that I showed earlier, the bat and the bear have many more linkages. This is the proportion of the important linkages -- many more linkages that had high climate threat versus low.

The snake actually has the reverse. It has more linkages that were important that had the low climate change threat. Dividing that up further, by the other two metrics, the other two metrics of land use change and level of protection.

In the legend below, these are the same bars as in the left figure, but just broken down now into for low and high climate change, what were the other metrics?

Again, the snake had more important linkages that were climate change refugia, or with low climate change threat, but those also tended to have a pretty high rate of other stressors combined, which is that darker black.

Higher land use and lower protection. The bat and the bear...the bat in particular had a high proportion of linkages with that high climate change threat and they also are in a set dark color, which is both stressors are high -- the high land use and low level of protections.

We can map those for the three species for their important linkages. Again, in their maps with the linkages colored according to that earlier figure I showed with the reds and the blues, so I'm putting it there for your convenience.

Again, not surprisingly, the snake, like we saw in the other results, has a lot of those blues. A lot of the low climate change threat, and a lot of them are the darkest blue, which is you might want to add protection. You might see a high degree of land use change in those linkages and they have a low degree of protection.

The bear actually had fewest linkages overall but also had the fewest linkages that were important to the network. Most of those are one of the red colors. The bat also had mostly red with a few of the blues with low climate change threat there.

The next thing we did was to kind of put this into more of a common currency across the three species and also just for visualization purposes, we overlaid the Omernik Level III Ecoregions. The ecoregions here that are not colored, that are white, did not have any linkages or very little area of linkages, that fell within them -- or important linkages, I should say.

We overlaid the ecoregions on the important linkages. These are basically the predominant categories that came out in terms of the largest area of this connectivity network of the linkages that overlapped each ecoregion.

You can see some similarities. Again, just species by species, the snake has a lot more of those blues and grays. Especially in the north, in the central regions, the bear has a few of those and the bat has fewer.

In terms of the commonalities across species, on those coastal plain ecoregions there are two coastal plain ecoregions for which climate change set was high. Expected land use change would be high by the middle of the century, and the degree of protection was low.

Those were the only two that matched up across species. This is just an example to show how we're applying this relatively simple framework here for the three species that we were mapping connectivity for.

Just in summary, I wanted to just show our framework, which is based on some simple concepts about climate adaptation and climate refugia and how we're thinking about it to inform some priorities or to start informing some priorities for conservation of connectivity, and applying it to our three species, I just wanted to show that case study.

It would be interesting to see it applied to other species and how those results might be similar or different. For the species that we did look at, the combined threats from climate and land use change and low levels of protection were common.

Although they're using similar habitats, they differed in their threats and conservation priorities, and especially when we look geographically.

Again, we saw that snakes had a lot more of its linkages that were climate change refugia. The bat and the bear had more linkages that needed adaptation measures.

This is just an example. We had our thresholds that we use. We could change any of these and see how that might affect things, but it's just a starting point to talk about some relatively simple metrics to inform conservation priorities.

A good next step would be selecting parcels, specific actions on those parcels, and using some prioritization algorithms, maybe like Marxan, to dig into it, one or more key linkages and to prioritize conservation or acquisition of lands, etc.

With that, that's the end of my talk. I appreciate you all listening. I'd be happy to answer questions if you have them. Thanks.

John: Thank you, Jen, for your presentation. As you mentioned, if you have any questions regarding the presentation, feel free to throw them into the chat box. There's also the Q&A box. If you want to throw them into either of those boxes, I'll see them and we'll hopefully get you an answer.

Bam! Got one right now. Can you expand on the natural history of the species to explain the differences in the results?

Jennifer: That's a good question. I've been trying to comb through some of the results and it's a little bit complex because the results of climate suitability not only depend on the habitat of the species, but also the change in climate and the change relative to the region as a whole.

I was trying to, in particular, think about the snake and why did it do better. Part of that has to do with that it's a little bit of a generalist but not too much. The regional average change in suitability was...

The linkages happen to be in places of greater suitability in the landscape as a whole. The connectivity algorithms we happen to choose were places where the suitability didn't change as much.

Also, the fact that the bear had fewer longer linkages and a fewer number of habitat cores in general, meant that it was more susceptible to changing climate. Honestly, the factors are complex and difficult to pull apart. If anyone here has some ideas on that, too, I'd be happy to hear them, too.

John: I hope it's Romana. I hope I got that right. I'm not sure exactly if that was your question or if you just popped up. I'm going to unmute you though. Romana, you should be able to speak over the line now, if you want to give us a shout out. If you have a question or that was your question, I'm not exactly sure.

Romana: Can you hear me?

John: Yes.

Romana: That was my question. A lot of it would maybe be habitat requirements of the different species and how those were arranged on the landscape. I didn't know if something about how they dispersed or...that that wouldn't be included in the model.

Jennifer: They're too different in their dispersal. The home range was considered with the habitat nodes, but the dispersal itself explicitly wasn't there.

John: If anybody else has any other questions...

Got another one. Let's see what it says. Looks like Tara? I can't exactly pull them out. Let me see if I can make this bigger. There we go.

Are there regulatory drivers to encourage conservation actions for these species in the southeast? For example, are they federally-endangered species?

Jennifer: That's a good question.

I know that the bat is on some state wildlife action plans and the snake is on some too. The snake and the bear are relatively widespread. I'm pretty sure they're not on any federal endangered species list. I'm not sure about the bat.

These are all relatively widespread in terms of their habitat use across the southeast, with the bat being the most restricted. There are species of some conservation concern, especially the bat. If anyone has any more specifics on that, it's been a little while since I looked at all the State Wildlife Action Plans.

I don't recall which states have them on their lists, but they were of concern to the landscape conservation cooperatives or they are of concern and their habitat. The bottomland hardwood habitat is of concern also.

John: We do have a few other questions. In your example, why did the snake do relatively well in terms of climate change threat?

Jennifer: I kind of answered that before. It's a complex answer but it's because it has to do with the fact that it's somewhat of a specialist but also uses a wide-range of habitats. It covers a range of habitats that have varying degrees that affected climate change and also degrees of expected urbanization.

In the results, the more linkages did better than the other two. The bat is more restricted and the bear is more a generalist but its habitat includes some ag lands in places that are near urban areas and would be expected to be converted with urbanization. I don't know if that answers the question?

John: What other stressors besides urbanization did you leave out or which others would have been good to add?

Jennifer: That's a really good question, especially in light of the recent hurricane. We did not consider sea-level rise, which directly on the coasts would be certainly a factor. More importantly than that, the potential for storms, storm surge, and flooding in coastal areas would be very important to consider in this, especially for the bats and somewhat for the snakes because those two species had a lot of linkages right along the coast that were important.

There was a recent study probably published last year or so by Paul Leonard and others which did take into account sea-level rise. It'd be interesting to compare or to look at the importance of sea-level rise to connectivity in their study.

That was important in their study and would be interesting to look at the degree of its impact. They also used the bear and the snake in their study. I haven't compared between this study and their study, but it would be interesting.

They actually mapped future connectivity. Rather than sticking with the same existing connectivity networks, they mapped changing connectivity through time.

Another stressor would be the potential for bio-energy development in bottomland hardwood forests. That's one big thing that folks talk about a lot, especially on the coastal plain is harvest of bottomland hardwood forests for biomass for bio-energy. That would be important for these species since they use bottomland hardwood forests. We didn't take that into account.

I see a chat question about ground-truthing for the linkages. I can answer that. We have not done ground-truthing for those linkages. A part of the study that I mentioned but didn't go into was this comparison of multiple connectivity algorithms, tools, and data inputs.

We haven't done ground-truthing but we have done a lot of work looking at multiple connectivity models and their overlap. For each given species, we've used a range of connectivity tools and a range of input data including movement measurements observations, at least for the bear, and looked at the relative differences.

They do make a difference in the outputs. Part of our work is to move toward an ensemble of connectivity models which I did not present here, but such an ensemble might look at the places where multiple models have predicted the connectivity.

That's not ground-truthing but it's at least some measure of potentially maybe some confidence in the model connectivity.

John: Looks like we have two questions that touch on the same thing. Is this methodology applicable for aquatic ecosystems as well and are you or anyone from climate centers doing this type of work for any aquatic species?

Jennifer: The short answer is I don't know if anyone is doing it. I would think it would be applicable for sure. Some of the specifics may change but thinking about climate threat and then the threat from other stressors is certainly relevant for aquatic species.

Someone who's an aquatic expert would certainly have ideas of how the inputs might change. Certainly broadly this framework would be applicable for sure.

John: I think this addresses most of the questions that have come in. Thank you for your presentation and thank you for everyone who participated today. This was a really good webinar. Thank you very much.

Jennifer: Thanks.