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Webinar Transcript

Fish Habitat and Climate Change: A Coarse Scale National Assessment with Finer Scale Assessment of Midwestern Streams and Lakes

Speakers:
Yin-Phan Tsang, Post-Doctoral Researcher, Michigan State University
Damon Kruger, Post-Doctoral Researcher, Michigan State University
Bill Herb, Post-Doctoral Researcher, University of Minnesota

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Ashley Fortune: Hello, everyone, from the U.S. Fish and Wildlife Service's National Conservation Training Center in Shepherdstown, West Virginia. My name is Ashley Fortune, and I would like to welcome you to today's broadcast of the NCCWSC's Climate Change Science and Management Webinar Series. This series is held in partnership with the U.S. Geological Survey's National Climate Change and Wildlife Science Center. Today's webinar will focus on the topic of managing the nation's fish habitat at multiple spatial scales in a rapidly-changing environment and climate. We will introduce our four speakers momentarily, but first, I would like to remind you of a few logistical details.

First, this webinar will be recorded, and it will be available approximately one to two weeks after the presentation. Holly Padgett will send you all an email once the recording is posted. Second, the speakers will be providing their contact information at the end of the presentation, so you will also have that.

All of your phones are currently on a global mute, and they will continue to be so during the presentation so we can hear the speakers. The speakers will be showing their presentations full-screen, however, you can always return to the main screen by pressing the back arrow. This will allow you to use the chat feature if you have any questions during the presentation.

At the end of each presentation, we will open the conference for your questions, and then the speakers will respond to any chat questions or comments at that time.

If you would like all the attendees to see the comment or questions that you have posted, please remember to use the drop-down arrow and select All Participants. This is located in the Send To line.

All right, now, without further ado, I would like to welcome Dr. Shawn Carter, Senior Scientist at the USGS National Climate Change and Wildlife Science Center in Reston, Virginia.

Shawn, would you please introduce our speakers?

Shawn Carter: Great, I'd be happy to, and thank you Ashley. Today, it's my pleasure to introduce four speakers that are representing a second component of a large project that we funded. The first speaker, Yin-Phan Tsang, is a Research Associate at Michigan State University. Her research involves linking hydrology and aquatic ecosystems and investigating physical processes related to climate and land use change. She currently has research projects with the Northeast Climate Science Center and also the National Gap Analysis program.

Damon Krueger is a Research Associate with Michigan State as well. His work includes predicting the effects of climate and land use change on stream fish habitat in Midwestern streams. He's currently conducting an assessment of Columbia River Basin's salmonids with respect to habitat conditions and interspecific interactions.

Our third speaker, Bill Herb, is a Research Associate at the University of Minnesota, St. Anthony Falls Lab. His research interests focus on computer modeling of hydrology and water quality, including the prediction of urbanization impacts on stream hydrology and temperature and projection of climate change impacts on fish habitat.

Last, but not least, Dana Infante is an Assistant Professor at the Department of Fisheries and Wildlife at Michigan State. Her interests and research include understanding the influences of landscape factors on stream fish and their habitats. In addition to being a co-principal investigator on this project that's going to be discussed today, she also is leading condition assessments of the nation's rivers, which are being conducted for the National Fish Habitat Partnership.

So, four wonderful speakers that we're going to hear from next, and with that, I'd like to turn it over to you all.

Ashley: Dana, go right ahead.

Dana Infante: Thanks very much, Ashley, and thank you all for joining us on the call today. As Shawn mentioned, I'm going to be speaking about a large multifaceted project called “Managing the Nation's Fish Habitat at Multiple Spatial Scales in a Rapidly Changing Climate”. Those of you who were on the call last month got an overview of a portion of this project. It's my privilege today to help introduce the components that comprise the rest of it. I'm going to switch to full screen. While the previous slide showed many of the principal investigators on this project, the teams that these PIs are a part of are led by some really amazing folks who did the majority of the research, the data management, and the data compilation. Today, you're going to be hearing from William Herb, Yin-Phan Tsang and Damon Krueger. I'd also mention that there are others on the call who have contributed again to a lot of the data and the analysis.

As Shawn mentioned, this is a multifaceted effort that occurred throughout the conterminous United States. The emphasis of this project was to perform a multiscale analysis to help provide differential pieces of information that could be used collectively to assess impacts of potential changes in climate and land use on aquatic habitats. The scales, or facets, to this project are represented by the notion of focusing on populations, larger scale work targeting regional fish communities, and a national scale assessment that was intended to provide a backdrop or estimate of changes in conditions in areas that were not addressed by the regional efforts.

In the previous call, we focused on the two studies targeting populations and on a regional study in the Lower Colorado River Basin. Today, our speakers are going to be talking about an assessment occurring in upper Midwest coldwater lakes, one targeting upper Midwest streams and stream fishes, and then an overview of the national assessment that we conducted.

I wanted to mention elements of the data that have proved critical to all of these various regional and national assessments that we've conducted, there were two pieces of information that were developed specifically for this project by PIs and teams of researchers. These included downscaled climate projections. With these downscaled climate data, the researchers were able to use estimates of changes in water temperature and stream flow regimes, in some cases, to estimate potential changes in aquatic habitat. We, also, had projected land use data that helped provide some context for understanding how additional changes could be affecting fish and fish habitat. These data were critical to all of the change assessments, and essential for characterizing vulnerability to these projected future changes.

Craig spoke about the details of our climate data and our land use change data last week, but I do want to mention that the climate models were downscaled by Steve Hostetler and his team. We had three climate models to use at the national scale. They're listed on this slide. They include GENMOM, the ECHAM5 and GFDL. The downscaled estimates were applied at a 15-kilometer grid. We summarized information, daily information, into multiple time steps over five year periods of time.

The variables we had for use in the various change assessments, included things like projections in air temperature, precipitation, soil moisture, evapotranspiration, et cetera.

Development of the land use change data was led by Bryan Pijanowski and his team at Purdue University. They began with the 2001 National Land Cover Data Set as the base layer. Data were summarized at the 30-meter scale, and we had change estimates specifically for urban land use and agricultural land use in ten-year increments. Urban land use was projected out to 2100, while agricultural land use change only went out to 2040.

So with those core pieces of data available, again, projected changes in climate and projected changes in urban and agricultural land use, that was provided to the various teams for the respective work to describe changes in fish and fish habitat.

I want to now introduce the speaker for the first regional study to be covered today. This is Dr. William Herb coming up next from the University of Minnesota. He will be speaking about changes in coldwater lakes.

[silence]

Ashley: Bill, are you on mute?

William Herb: No, I'm not. I'm waiting for...Let's see. OK, I do have control now. Thank you. I will be speaking today about the project looking at cold water fish habitat in lakes in the Midwestern region. Lucinda Johnson, at the University of Minnesota-Duluth, was the principal investigator on this project. Our collaborators included Don Pereira and Pete Jacobson, at the Minnesota DNR, and Hines Duffen at the University of Minnesota.

I will go to full screen here and talk about the goals of the project.

First of all, we wanted to take a look at how future land use change might impact nutrient loading and lake trophic status in these Midwestern cold water lakes, and then make some projections about how these changes in trophic status will impact cold water fish habitat along with expected climate changes.

Our cold water fish species of interest, for this study, included Tullibee (or Cisco), Lake Whitefish and Lake Trout.

This diagram describes the physical connection between nutrient loading and cold water fish habitat, where phosphorus loading, coming in from the lake shed promotes plankton growth in the hypolimnion of lakes. As the plankton grow and die off, they sink towards the bottom of the lake and start decaying. That depletes oxygen in the hypolimnion of the lake, where the cold water fish like to live.

So, increases in phosphorus loading can increase productivity in the lake, and increase this oxygen depletion in the hypolimnion. That effect builds on any temperature increases in the lake due to climate change, longer open water seasons and things like that.

Our study lakes spanned three states, Minnesota, Wisconsin and Michigan, and four ecoregions. Most of the lakes in our study are in the Northern Lakes and Forests ecoregion and North Central Hardwood Forest ecoregion.

I should say, when I say cold water lakes I mean lakes that have populations of these fish species: cisco, lake trout, and lake whitefish.

Of the 1,154 lakes that we identified for the study, about 250 had sufficient phosphorus data and so forth, to be included in our phosphorus loading model.

One of the major pieces of this study was to put together a model for relating land use and climate to phosphorus loading and in-lake concentrations of phosphorus and trophic status.

To do this, we used linear, mixed model regression relationships. We made one regression relationship for each ecoregion, using log transformed variables. The significant lake shed variables, in these regressions, were urban fraction, corn fraction, forest fraction and then annual runoff depth or precipitation depth, as a climate based parameter.

The regressions were based on in-lake phosphorus concentration observations, from 1990 to 2008. What we were predicting in the regression relationships was actually an annual phosphorus loading grade to the lakes. Then I converted that to an in-lake concentration, subsequently.

You can see, at the bottom of this slide, that the R-squared of our predicted concentrations range from 0.55 to 0.68, depending on whether you look at it on a linear scale or a log scale. The in-lake concentration predictions turned out quite well.

With in-lake concentrations in hand, the next task was to relate these two actual cold water fish habitats. To do this, we used a parameter called TDO3, which is the temperature in the lake at the depth where DO is equal to three milligrams per liter. For cold water fish species, you want this to be a low temperature, meaning that there is sufficient oxygen down in the deeper parts of the lake, where the temperature is suitable for these species.

This TDO3 parameter can be extracted from temperature DO profile measurements in lakes. It has been found to be a good predictor of cold water species' presence and absence. TDO3 can also be empirically estimated from regression relationships, using air temperature, in-lake phosphorus concentration and a couple of other parameters. So, that empirical model is the coupling we get between in-lake phosphorus concentration and cold water habitat.

This is all work primarily done by Peter Jacobson at the Minnesota DNR. He went further to relate this TDO3 parameter to a habitat score specific to each cold water lake species, where a 100 habitat score is an excellent habitat and zero is a very poor habitat. You can see in this figure that cisco are actually the most tolerant species for warmer or higher values of TDO3, whereas lake trout are the least tolerant of higher temperatures.

With the phosphorus loading model in hand and this TDO3 empirical relationship in hand, we are then in a position to make some projections about future cold water lake habitat. In particular, we can use future land use as an input to phosphorus loading, model future climate data as input to both the phosphorus loading model and the TDO3 model, and calculate the future changes in phosphorus concentration and then the corresponding changes in TDO3 and these habitat scores.

We have done that for the combined effects of climate and land use, and then broken it down into individual responses, as we will see.

The inputs to the model are the land use and climate data that Dana already mentioned. I will gloss over this slide a bit, other than to say that both the land use data and the climate change data ended up being quite important in determining our lake responses.

I will go through some results now. I am going to focus on results obtained using the GENMOM model climate data. I will focus on the Northern Lakes and Forests and North Central Hardwood ecoregions, because that's where most of the cold water lakes are. I will focus on cisco habitat, because that is the species we were most interested in for this particular study.

So, let's look at some driving variables first.

In the Northern Lakes and Forests ecoregion, the plot on the left shows the change in air temperature, summarized in 20 year blocks, for each lake in the Northern Lakes and Forests ecoregion. You can see, from the historical period to 2080, that we are getting a median increase in air temperature of about 2.5 degrees Celsius but with quite a bit of variation across the region.

If you look at the graph on the right, that shows the projected change in in-lake phosphorus concentration for the Northern Lakes and Forests lakes. You can see, in this plot that the median concentration, that dark line in the box plot, doesn't really change very much. So land use change was not really, generally, a big deal for the Northern Lakes and Forests lakes. But there are outliers that did see quite high impact of land use and subsequent increase in in-lake phosphorus concentration.

Now, we can look at the responses for Northern Lakes and Forests lakes.

The graph on the left shows the decrease in the cisco habitat score for these lakes, projected all the way out to 2080. You can see, going out to 2080, that the median lake decreases by a score of about 15 out of 100. That's a fairly significant decrease. But there is also great range of variation on these decreases. Some lakes are impacted much more and some are impacted much less. The lake response in 2080 is shown in the map on the right.

Two things to notice here are, number one, there is a gradient of response from east to west, so that the Minnesota lakes are getting hit a bit harder than Wisconsin and Michigan. That is because of the changes in air temperature are a bit more, in particularly northern Minnesota.

Also you can see that there are some red dots towards the southern end of the Northern Lakes and Forests ecoregion. Those are lakes getting hit by some agricultural production creeping its way north.

Now, turning our attention briefly to the North Central Hardwood Forest lakes, the changes in air temperature on the plot on the left are fairly comparable to the Northern Lakes and Forests. Just a little bit less increase in air temperature, but on the order of two to two and a half degrees Celsius. However, looking at the plot on the right of change in in-lake phosphorus concentration, you can see that there is a significant increase in phosphorus concentrations, on the order of 10 to 20 megagrams per liter with some variation between lakes.

But the median value does see a very significant change, compared to northern lakes and forests. That is due to the combination of urbanization and increased agricultural production.

Looking at the response of these North Central Hardwood Forest lakes, on the left, once again, is the change in the cisco habitat score. You can see these decreases are a bit higher now, on the order of 20 to 25 points, out of 100.

On the right, you can see, once again, the distribution of the lake responses across the region, by lake. You can see, actually, that most of the lakes in this ecoregion are in Minnesota. But within that area, there is actually quite a variety and range of responses, once again.

This last results slide summarizes the median response in habitat to land use and climate change for each ecoregion. This is the typical lake response, in each of the four ecoregions in the study.

For example, you can see, in the Northern Lakes and Forests ecoregion, in the upper left, that the combined response of the habitat score is mainly due to air temperature, whereas the individual response to urbanization and corn production is almost insignificant in that ecoregion. For example, in the Southeastern Wisconsin Till Plains ecoregion, directly below that in the lower left, you can see that the response of these lakes to urbanization, corn production and air temperature increases are all pretty comparable in size, and they add up to be a significant number.

So, depending on what ecoregion you're in, the land use change impacts are more or less significant.

To summarize, overall air temperature increases tend to have the biggest impact on cold water habitats, in these lakes, according to our models. However, in many regions, urbanization and increased agriculture can also have very significant impacts. That's more of a localized effect, compared to air temperature.

Overall, habitat in the Minnesota lakes is projected to change a bit more than the other two states, because of the increased change in air temperature, but there is great diversity in the lake responses, within this region.

The results I gave here today are for the 255 lakes that were included in the phosphorus loading model. We're currently working on ways to expand that out to a larger set of lakes.

That concludes my portion of the presentation. I can take questions now or at the end of the webinar.

Ashley: Excellent. Thank you, Bill. Bill, can you just go ahead and press that stop button and bring us back to that main screen. Thank you.

You guys can text chat your questions, right now, for Bill. Or you can wait until the end. Or you can use the "raise hand" icon that's located between the participant list in the chat box, and you can ask your question over the phone.

If you are planning on asking your question over the phone, just remember to take off the global mute by pressing star six when I call on you.

We have a question from Joy, that says, "Are there methods to reduce phosphorus loading to the effected streams?"

William: The answer to that question is, "Yes." One of the motivations for this project was to help the Minnesota DNR and the DNRs in other states, to prioritize their strategies for buying up land to help protect particular lakes and particular streams. If there are particular lakes of interest, they can perhaps acquire parcels of land to protect that land from development in the future. When development does happen, there are certainly best management practices that can be used, for both agriculture and urbanization, to reduce the phosphorus exports.

Ashley: We have another question from Jordan. He says, "How well does the TDO3 model reproduce dynamics in historical measurements?"

William: The TDO3 model was developed by Peter Jacobson, at the Minnesota DNR. The model makes projections over relatively long periods of time, say 10 to 20 years of average data. But I believe that the R-squared of these relationships that he developed was on the order of 0.6 or so.

Ashley: Then we have another one from Gretchen that says, "Can you tell us a little more about the species-specific habitat scores that were generated?"

William: Again, this is work by Peter Jacobson. He basically had quite a lot of in-lake fish sampling data, along with a lot of temperature and dissolved oxygen profiles, from these lakes. Basically, you look at a number of lakes and determine what the TDO3 parameter was in the lake, and perhaps average that over a number of years. And then look to see if that lake has particular cold water species. By compiling this data together and doing logistic regression models, you can create these habitat scores, which are basically the probability of presence of these particular fish in a lake, with a particular value of TDO3.

Ashley: Then we have one more, from Mark. It says, "In addition to the change in water quality, are you also concerned with potential effects of changing water quality, e.g. via a water supply and stress index model?"

William: Are we considering water quantity? Is that the question?

Ashley: Yes. Quantity.

William: OK. We did not do a lot of work on that particular aspect. In general, the climate change forecasts, if anything, show slight or moderate increases in precipitation in the future. So, we're not expecting a drastic change in annual average stream flows and lake levels. But that would certainly be something to look at in the future, if we had some good hydrology models in hand. But no, we have not looked at that yet.

Ashley: All right. Mark says, "Thank you." We'll take one more, from Gretchen. It says, "Did you use lake-specific input data, besides TP and air temperature, to predict lake-specific responses, such as depth, area, etc?"

William: Yes we did. The data that we used for each lake included lake morphometry data, the lake area, the mean depth and the maximum depth. It also included the lake shed area. For the land use parameters, we had to attribute the future land use projections over the local and cumulative lake shed areas, and use that in the loading models, and also to predict things like residence time. There were actually quite a few lake-specific parameters used. I'm actually, right now, in the process of trying to sort out which lakes tend to respond the most and which lakes tend to respond the least to these land use and climate change impacts.

Ashley: Thank you. I'm going to turn it back over to Dana. Then, if you guys have any more questions, we will be taking them again, at the conclusion of the rest of the presentation. Thanks. Dana?

Dana: Thanks a lot. Next slide. Just a broad take home point, regarding Bill's presentation: he did an excellent job of sharing with us specifically how some of these cold water lake habitat characteristics are likely to change with projected changes in climate and land use. I just want to emphasize that these results represent specific mechanisms by which changes are likely to affect valued fish species within these systems. The next speaker is going to shift system types and speak a little bit about streams of the region. With that, I'd like to introduce Dr. Damon Krueger, who'll be talking next.

Damon Krueger: Thanks, Dana. Thanks, everybody, for joining the call. I'm going to talk about some of the work that I've done previously, which is an attempt to assess the effects of climate and land use changes on some Midwestern stream fish habitats.

Like the other studies that have been discussed thus far, this is a regional study, again, comprising a large area of Minnesota, Michigan and Wisconsin, which has a little bit more than a 120,000 stream reaches, as determined by confluence to confluence or confluence to termination. There are diverse stream types in the region. That's likely due to having three level one ecoregions present. There are four different thermal classes, if you consider the cool water transitional streams. Of course, there are characteristic fish assemblages that go along with each of those, the different thermal classes, in addition to the different regional assemblages.

Then, of course, this area is quite unique, in terms of its groundwater resources that are quite abundant in the region. That sets it apart quite a bit from the remaining areas of the country.

One of our main objectives was to use fish species as a "surrogate measure" for in-stream habitat. This is simply because it's very difficult to go through and sample in-stream habitat, especially when you're talking about over 120,000 stream reaches -- so thousands upon thousands of miles of stream reaches. Instead, we can use landscape scale measures to try to quantify some of those in-stream habitats, by making correlative predictions.

What we wanted to do was, identify changes in fish habitat that were due to projected climate and land use changes. Those were things that Dana had touched on before -- climate coming from Steve Hostetler, out of Oregon State, and land use changes coming from Brian Pijanowski and crew over at Purdue.

Perhaps the most important thing that we wanted to do was to share appropriate information with watershed managers, lake managers, basically just resource managers. The reason for that is that there's such an over-abundance of climate data and maybe even land use data. It's tough to actually say what you can do with these data.

What our goal was was to try to make climate data usable where it counts. To say, "Here's what we think is going to happen based on these climate projections, and here are some suggestions for how you might be able to ameliorate or otherwise, for these different areas."

Jumping right into how I actually determined what happens in response to these climate changes and land use changes, the first aspect was to model stream temperature.

In order to do this, I used an Artificial Neural Network. That was the iQuest software from Advanced Data Mining Incorporation. The data requirements are actually relatively minimal, with respect to some of the mechanistic models that you may have read about. This, of course, would be nearly impossible to do a mechanistic type model because of the scope, as well as the data that would be required. You can see, in this case, that there were about 800 sites for Michigan, 500 for Minnesota and 377 for the state of Wisconsin.

Those actually were quite sufficient, in order to build this correlative type model that would be able to take in daily data that was actually collected from these streams, along with the landscape data and the climate data. Then it could, as an output, spit out, again, daily stream temperature data. From there, we can essentially make a limitless number of metrics that would describe the stream temperature regime of any given stream for which we have data.

Then from there, we could actually go and use this model to predict the daily mean stream temperature for all streams in the region.

Again, this was a pretty efficient way in which to predict stream temperature. We had an R-squared of around 0.75, which is actually quite good, especially for state-scale models. I believe that's something I forgot to say, that each of these states had a different model associated with it. But they all performed about equally well.

For the stream flow models, what I did is not a neural network model, like I did for the stream temperature, but instead a multiple linear regression method that Paul Seelbach and Leon Hinz came up with for an analysis of Illinois, Wisconsin and Michigan streams several years ago. They predicted exceedance flows, and again this is a state by state model.

I developed three different models for each state. One would describe the mean annual flow, one would describe the spring peak flow, and then the last would describe the summer low flow.

You can see that there are considerably fewer sites associated with each of these states -- Michigan was about 120, Minnesota, 71, and Wisconsin, about 85. These were all from the USGS gage stations.

There are actually quite a few more gauge stations present within each state. But based on all the criteria that we put forth, these are the number of sites that actually satisfied those criteria and then were able to be used in our modeling analysis.

USGS gage data were used as required data, as well as precipitation data, which we got from two different sources. One was the PRISM data, which we used as our "current data." Then we used three different AOGCMs or the general circulation models, the downscaled versions of those from Hostetler et al., that Dana talked about before.

Again, we used land use data from Pijanowski. Then we also used several layers of landscape data that are present at the national scale.

These models all performed quite well, upwards of about 90 percent for R-squared, for some of the models, maybe down to about 75 percent for some of the others. But again, in general, they performed very well, especially for state level models. Finally, we can determine how fish respond to these different changes in thermal and flow regimes of these various streams.

What we did was to actually use species groups and to group them together, to get more of an ecosystem-based approach to management rather than a species by species management approach. You can see there are quite a few data points for different arcs with fish, over 5,000 points all together, for all three different states. We were able to make some pretty strong models, as a matter of fact.

We used two different types, primarily, to model the distribution of fish species. That was based on presence/absence. The first way was to use Random Forest. This is a very robust method, because it uses thousands of trees and therefore is not driven by unusual circumstances, but rather by typical observations. So you're not being thrown off by outliers. We also used classification and regression trees, or CaRT.

This is fairly similar to Random Forest, but here we have more of a variable prediction relationship that makes it so that you're actually looking at each tree as you build it. This allows you to interpret and explain what's going on within each model and follow it, step by step, through. Both have their bonuses. Both have their negatives. But if used in tandem, I think you can be pretty certain of an outcome, so to speak.

And then again, the predictions that we're getting are essentially the same for both models. We would use the best model, whether it was CaRT or Random Forest. So whichever one had the highest score would have been used for that particular species group. Then each of the models is then predicting the presence/absence for the given species group. Getting on to some of the results, what I'm showing here is the results for the stream temperature model.

This is just one example. It shows the departures from current. From 1997 to 2042, how would these streams be predicted to change? You can see it goes from a decrease of three and a half degrees, which you can see in Central Minnesota, the dark blue, all the way up to a three and a half degree increase in temperature, which, in this case, doesn't look like there is a whole lot. Most of the increases seem to be from a half to one and a half degrees.

But at this time step, oddly enough, there are a number of streams that show a cooling, along with a large number of streams that show a warming. Of course, some of the differences between the states are somewhat noticeable. Again, that's likely due to the fact that each state was independently created, instead of having simply one stream model to model the entire region.

If we then look at the next time step, which is 2062, for the same AOGCM predictions, we can see there's a significant warming across the entire region. There is still that one patch in central Minnesota that shows a slight cooling. In general, we see quite a substantial warming throughout the entire region.

Flow is a little bit harder to quantify, especially to visualize. I've tried to just show it. Here is, essentially, the change in exceedance of, again, departures from current, from 1997 to 2062, which is the latter time step I showed previously.

You can see that we go from no change, essentially, which is the grayish blue, all the way up to the red, which I'll just call a large change. It's hard to visualize when it's cubic meters per second per kilometer squared. This is the exceedance yield, I should specify. This is going to be based on the area of the stream itself. Again, you can see there's a pretty large increase throughout a pretty substantial portion of the region.

If we go and we plug those stream flow and stream temperature predictions into our fish models, first of all, we can look at what I've called the "cold water" or otherwise known as species assemblage one, which I found from Travis Brennan et al., from a few years back.

This is, essentially, salmonid habitat. Here's a look at the current distribution of those cold water species. I should mention that, if there's one species present out of the group, then the group itself is proposed to be present in that specific reach.

Here, you can see the current distribution of those species. If we look forward to 2062, again, based on just one of the AOGCMs, you can see that there is a substantial decrease in the distribution of those species within the group.

Again, black is present. All the gray areas are now absent. Another way that is helpful to look at it is by looking at whether the species was present originally and present in the predicted time step. What you see: black shows that it was present previously and is present in the future. Gray, of course, is absent both time steps. Blue shows a gain of habitat. There's only one small area in southwest Michigan that actually shows a gain of habitat.

By and large, you see a species that was present and then lost that habitat due to warming or flow or both. That's the red. So, considerable habitat loss, according to the outputs from this particular AOGCM.

There are, of course, going to be more products coming from this particular work that I've been doing. Again, we have predictions based on the output of three separate climate models. Those would be the GENMOM, the EH5 or the ECHAM5, whatever you want to call it, and the GFDL.

So, that gives us a pretty good range of possible futures, from a cooler future to a very warmer future, perhaps, or anything in between.

Of course, we have stream temperature, which is predicted at daily time steps, and again, can be turned into just about limitless metrics that would describe the temperature regime of the stream. Stream flow is going to be described by three primary metrics, which are going to be the Q50, Q10 and Q90 exceedance metrics.

Then we've also got the fish group distributions, as well as the delta of those distributions -- so how do they change across time. I've got 15 different species groupings that describe various metrics that describe the streams. Fish that respond to flow, fish that respond to temperature, as well as different metrics.

We've got six different time steps that we can look at. The current of, course. Then 2022, 2032, 2042, 2062 and 2087.

Finally, we've got more or less a plug and play capability with this type of model format. This can be easily updated or expanded, with new AOGCM results or land use results. We can incorporate new climate models. We can incorporate new ways to look at land use changes. In that way, we can provide results fairly quickly and easily.

Next comes the question of who uses this information. We're hoping that a lot of people will use this information, or at least give us suggestions on what could be useful.

Anyone from the U.S. Forest Service, the Fish and Wildlife Service, state agencies have been very instrumental in getting this work up and going, and seem to have quite an interest in using the information as well. The great thing about this type of modeling approach is that it allows for prioritization of fish habitat. We can ask a number of different questions, such as whether the species or species groups have an economic, ecological or even cultural significance.

We can look at areas of fish habitat and determine which are more appropriate for restoration, and/or conservation activities. We can do this by looking at our predictions that would guess whether or not the good habitat now is also going to be a good habitat in the future.

One of the aspects of this project that we really decided to stick to, from the beginning, was that our results are going to be interpreted by those that used the results themselves and not by us.

These questions and the answers to them are going to be up to the managers themselves. How do they interpret and how do they place labels on what's good change, what's bad change, etc.

Finally, something that's fairly unique, as well, is that we can both identify problem locations with respect to habitat loss or gain, and we can also identify the mechanisms by which these changes are occurring.

Because of that, we can allow management to act pretty effectively and efficiently.

With that, I'd like to take any questions, if there are any.

Ashley: Thank you, Damon. If everyone can just look in the chat box, Bill has amended his previous answer to the question about water quantity. "We did do some very simple modeling of the projected annual runoff depth and found that increases in runoff depth tend to increase phosphorus loading. But that increase is offset by an increased lake flushing."

All right. Mark has a question. "Were projections of future stream temperatures stratified by flow source, i.e., spring fed Southeast Minnesota, versus surface runoff Northeast Minnesota."

Damon: I guess yes and no. What I did was, I had to run different...How should I say this? I had to choose variables that would describe the variability in stream temperature, based on the thermal regime that exists currently. Essentially, it would have been based on maybe a single year's worth of data, maybe up to three of four years of data. Generally, it would be based on one year of data and what category it fell into, whether it was cold water, warm water, or one of the transitional streams. We did not build a separate model for cold water versus warm water streams, if that's what the question is. But what we did do is use an equal number of streams that came from each of those four different thermal habitat categories.

I'm not sure, hopefully, that answers the question. But if not, please let me know.

Ashley: I think it answered the question. Mark says thanks. We have a question from Joy, and it says, "Perhaps building and restoring more wetlands would help reduce phosphorus loading to streams and lakes."

Damon: I'm sorry, could you repeat that please?

Ashley: Yes, absolutely. We have a comment from Joy, and it says "Perhaps building and restoring more wetlands would help reduce phosphorus loading to streams and lakes."

Damon: I assume that's for Bill, but I would guess that that's definitely the case.

William: This is Bill, and I would definitely agree with that statement. [laughter]

Ashley: Thank you. Then we have a question from Gretchen for Damon. It says, "Can you explain on your last point. It seems like your statistical approaches to prediction are based on correlations between your temperature and flow metrics and presence/absence. How do you identify mechanisms?"

Damon: We could do that by holding some of the various metrics constant and changing others, and see which are responsible for more of the variation in...now, this could be for temperature modeling, flow modeling or for the fish modeling. So we could essentially look at the mechanisms that are responsible for our temperature variation, for flow variation, as well as for differences in the distribution of the fish species. Let's say for a stream temperature, for example, I could plug in climate changes based on one particular model. Then I could hold land use constant in one run. Then I could also throw in changing land use in another run. Then look at the difference that would be attributed to land use, specifically. Then I could do the opposite and determine what changes are attributed to air temperature, specifically.

We could do something similar with the species modeling, but then it would just be a matter of looking at the differences in the distribution of species. In that case, you might want to look at a finer scale to determine maybe if there's a hawk that you're interested in to see how land use might influence the distribution of a particular species or a group in one particular hawk versus another.

Ashley: We have a question from Than. It says, "Can you explain the projected cooling in Central Minnesota?"

Damon: I cannot, really, to be honest. What I can say is that no matter what climate model that we use, it is present in all of them. I'm thinking that something's there and someone, hopefully, better versed in Minnesota streams than me can explain that, but I, unfortunately, don't have a good answer for that. I apologize.

Ashley: All right. I don't see any more questions. I'm going to turn it back over to Dana.

Dana: Thanks a lot, Ashley. We've had two examples of great projects that have highlighted spatially explicit changes in habitat likely to occur with climate and land use changes. I want to emphasize again, that these projects, due to differences in data availability at these regional scales, really help suggest specific mechanisms of how these habitats are likely to change.

I mentioned that at a national scale, in certain regions, we don't have the luxury of having sufficient data available to characterize these changes in aquatic habitats. However, it's still critical to have a nationally consistent picture of what might occur, i.e. where changes might occur.

With that, I'd like to introduce our next speaker, who will be describing a national project, Dr. Yin-Phan Tsang.

Yin-Phan Tsang: Thanks, Dana. For the following national assessment, I would like to first acknowledge my co-authors Dana Infante, Lizhu Wang, Damon Krueger, Daniel Wieferich, and Bill Taylor. They have been instrumental in this analysis. In the previous presentations, you have heard great modeling and assessment work at the regional scale. However, we do know that the climate change is a global issue and its impact on the ecosystem actually won't stop at the boundaries. We actually need consistent methods to describe these changes to allow us to compare those impacts, and allow us to prioritize those management resources when we try to do the adapting the climate impact.

For today's talk, I would like to first describe the assessment framework that we've done for this national scale assessment. Then I would like to give you an idea about how these assessment results can be used, and how can we use these results to link with other information for the management use?

I will start my talk with the spatial framework that we use. The spatial framework is the foundation of this large scale analysis. The spatial framework is the key for us to managing, analyzing and summarizing the data. We chose the NHDPlus as our spatial framework. It is a 1 to 100,000 scale river coverage. The basic unit of an NHDPlus is the stream reach.

There are a total of 2.6 million reaches nationwide. For each reach, the area that flows into the local reaches, we call it local catchment. For the area that flows into the stream network, we call it network catchment. For each reach, they will have attached local and associated network catchments.

In using this spatial framework, we can later on...This is a demonstration of how we can summarize the information. From local reach and catchment, we can aggregate them into a large catchment, or a large hydrologic unit. We can continue to integrate it into the EDUs or large ecoregions, or even to the state boundary. We can even integrate them into a large scale ecoregion, or even to a boundary that is interesting to all the management units or partnership.

Based on this spatial framework, we're going to do our climate assessment at the national scale. As Dana and the presenter before have mentioned, we have the climate data from Steve Hostetler. He modeled a climate projection using an A2 scenario.

One of the benefits of using these climate projections is that they provide various variables for us to using the assessment. For example, they have precipitation, air temperature, solar radiation, soil moisture, or growing degree days, etc.

On the other hand, we have more than 13,000 fish sites nationwide. This is an effort supported by National Fish Habitat Partnership, and USGS National Climate Change and Wildlife Science Center. We have a fish record between 1990 to 2010.

Having these information and data are great, but we are still lacking something. That's the habitat. We all know that fish live in the stream, and climate has to cast its influence on fish through the habitat.

Habitat could be affected by a lot of things. They could be water quality, sediment or geology, surficial geology. But the two major components to affect fish, and it's related to climate, are the flow and temperature. Therefore, we gather daily flow and temperature records to use in this assessment.

We filter the daily flow gages that have 10 years of continuous data, without gaps of more than five days. We then use the daily flow and temperature data between 1990 to 2010 to use in the analysis.

These flow and temperature daily records were turned into 171 flow metrics and 141 temperature metrics to describe the habitat condition that related to fish. For example, they could be high flow, low flow, or a seasonal maximum, minimum, and mean temperature at those given locations.

We then linked those flow and temperature gauges with the fish sample site that we have. Then we make sure the criteria are within 10 kilometers apart, with the same size stream reaches and no dams between them.

Now, we have all the data we need, but we still need to build the linkages to say something about how climate will affect fish. We performed this assessment. We used three questions to guide us to perform this assessment.

The first question we asked is which habitat condition fish will like and will support their living. For example, we used indicators species analysis to understand if fish like the high flow or low flow or different thermal conditions at the region.

We then asked what kind of climate metrics are strongly affecting or driving the habitat condition. For example, we used correlation analysis to find out the snow amount in the winter is highly correlated to the maximum high flow in a year at a given location.

The last, but not least, we want to know which climate characteristic will change in the future. That will give us the idea of what will likely to change in the region.

By answering these three questions, we established the link among climate habitat and the fish. We then confirmed these relationships using literature. We also consulted expert opinions to make sure that those known relationships have been captured in this linkage.

We then see in the selected climate metrics, along with the responsive fish group, also the natural factors that are already known that are important to fish in the multivariate regression tree (MRT). By doing this assessment, we eventually will have a climate driven fish habitat ecological classification.

We have performed the previous assessment with the nine large ecoregions throughout the coterminous U.S. Each region will have their own climate driven fish habitat classification that describes how the climate is supporting the current fish habitat.

This is a close look of what are the natural factors used in those classifications. As you can see, every region has its different natural factors being used in their trees. To see that the catchment area has been used for all the regions to do the classification.

Here is another close look on the climate metrics that we used in the classification. Just to point out that as we mentioned before, these climate models allow us to have a wide selection of climate metrics. We have used rainfall or no rainfall, snow, air temperature, growing degree day or extreme temperature day counts, or the ground temperature. Each of the climate metrics have been used differently throughout the regions.

Now that we have all the stream habitat classifications for all nine large regions, then we can apply the future climate projections on these classifications. We defined that a change in the stream class indicates a potential change in the hydrological and thermal conditions due to climate.

We have three models in multiple time steps. The GENMOM model is actually the most conservative model. Just a reminder that we have performed this analysis at the reach-by-reach scale. It's allowed us to summarize in our large unit because of our spatial framework.

In the following, I'm going to show you the GENMOM results in the HUC-12 unit. This is the fish habitat projection in 2020. We know that we have fewer fish sample at the large river site. We don't feel comfortable to project the habitat change at those large rivers. Therefore, they are shown as no results. It's blank on the map.

For the gray areas, those are the stream habitats that show no change in 2020. For the pinkish purple, those are the areas that have shown hydrologic or thermal habitat change by climate. This is the result in 2020. This is in 2030, '40, '60, and 2090.

By having this information, we can see the change across different regions at the national scale. What else can we see from this projection?

This is an example at the north Appalachian region that is showing the habitat change due to the change in growing degree day in the summer.

The growing degree day is the amount of accumulated heat. In the color showing here that if it's lighter yellow, it means that there is a decreasing number of the growing degree days. The darker yellow or orange is a gaining of growing degree day in the area.

So a manager at the region can base on this information to consider riparian zone buffer to accommodate those potential changes at the area.

This is another example at the upper Midwest region. The color is showing the area that will change due to the increasing or decreasing snow in the winter. Darker color indicates that there will be increasing snow in the winter. The lighter color means that there will be a decreasing snow in the winter.

Just to remind you that this is not just a climate projection. This is a projection of fish habitat that will change due to the increasing or decreasing snow in the winter. Also, we have found that this is highly related to the timing of the annual maximum flow in the area.

For the manager in the area, they could use this information to consider different -- like a detention pond for the potential high flow, or consider to limit the water withdrawal at the area that will decrease with the snow in the winter.

Here, just a quick summary about this framework that we have used at the national scale. We have quantitatively analyzed the available data, and this approach allows us to flexibly incorporate the knowledge that we have now from literature or experts.

We have done this assessment reach by reach, but the spatial framework allows us to apply to local or large-scale, which will allow us to do comparisons across regions, and the last but not the least, when we have better information, like fish or flow or climate, we can always improve this assessment.

The last slide that I want to show here is that, due to the time limit, I didn't have time to show the land use change result, but I just want to give you an idea that having this nationwide habitat change projection due to climate, we can compare them with those habitat changes due to land use. At the same time, let's not forget that we have fish habitat current conditions, as well. So combine all the input, all the best information we have, we can do a better informed decision when we try to prioritize our resources across the region at a large scale.

Thank you. I will be happy answering questions.

Ashley: Thank you, Yin-Phan. Could you press the stop button and bring us back to the main page?

Yin-Phan: Yeah, absolutely.

Ashley: Thank you. All right. Does anybody have any questions? They can be pertaining to Yin-Phan's presentation, or either of the other two presentations. [silence 1:11:08 to 1:11:31]

Ashley: All right, we'll wait for just another minute or so, in case people are typing. [silence 1:11:35 to 1:02:01]

Ashley: All right, Dana. Did you have any conclusions?

Dana: I just want to provide a few, quick closing points. We've had some great presentations today about mechanisms of change occurring in Midwestern lakes and streams. Yin-Phan's work described a broad approach showing potential changes due to potential responses of thermally and hydrologically sensitive groups of species. These differences, in part, were derived by differences in data available across these different regions.

If you attended the presentation last month, you saw the results for the Lower Colorado and for the Eastern Brook Trout Joint Venture region. This table helps to summarize how different number of sites with fish data, temperature data and flow data were big factors that needed to be considered in these respective projects.

At the same time, in hearing Bill's talk today, for example, he had a fairly good representation of lakes with phosphorous data, almost 30 percent, yet, there are a large number of lakes for which those data are missing.

A point I wanted to share about these projects is that, despite the results they've generated for climate changes, they can also be used to potentially prioritize systems or areas in which additional data could be calculated.

I don't know if Bill mentioned this in his talk, but, for example, his research group is considering ways to characterize phosphorous concentrations using Secchi disk depths. So, again, these results can help guide how data are collected and modeled into the future.

All of these projects made the most of available data. But in doing so there was, in some cases, trial and error in terms of determining which approaches were most appropriate. Through that process, a lot of knowledge has been gained by the various researchers, some of which at least is going to be shared in various publications.

Together, this suite of knowledge really does provide a great set of alternatives to potentially other researchers who may wish to conduct change evaluations in their respective regions. Again, they can look to some of these projects for guidance on how to work when data are more limited, when you wish to target response of a particular species or, for example, characterize specific changes in habitat.

With this multi-faceted analytical framework, one application coming from this project then, of course, is this notion of providing insights to new studies that, again, might be region specific or species specific.

I also want to emphasize the value of the spatial framework that all of the projects relied on. It's allowing us to do some next steps of actually looking at different project results in overlapping regions. How are they similar? Why are they different?

Damon emphasized this in his talk, as well. This spatial framework will easily allow us to bring in alternative data sets, new data such as alternative climate projections, new projected changes in land use, for example.

As Yin-Phan emphasized, these data together with other pieces of information, estimates of current conditions, socioeconomic data, data on conservation priorities, can really provide an enhanced view at multiple spatial scales for decision making.

Certainly, to the degree that we're talking about large-scale efforts, these projects relied on data and input from a variety of agencies. This slide lists some of the main funders of the research, with first and foremost being the National Climate Change and Wildlife Science Center.

The following acknowledgements are more specific to individual projects and acknowledge at least some of the many people who contributed data and effort on this project.

At this time, we'll sort of step back for any larger questions that people might have for specific researchers.

[silence 1:16:38-1:16:46]

Ashley: If anybody has any questions, please go ahead and use the raise hand icon, if you'd like to ask them through the phone, or just put the check mark so I know that you're typing. OK, we do have Gretchen typing.

Gretchen writes, "What has the response from managers been? Do they want to use this information to prioritize for protection, restoration, et cetera?"

Damon: Yes, we have had some pretty good responses from managers of different agencies in all three states. In fact, I got a pretty positive response from the Minnesota people last summer with respect to the stream temperature, flow and fish models. People have been pretty interested to see this stuff. I think there's a lot of interest in going forward with developing some new predictions and maybe even incorporating them into some future management planning. One other thing that I'll throw in, the data that I showed earlier, there are a lot more of them, but they've been incorporated into a Landscape Conservation Cooperative project in the Upper Midwest and Great Lakes LCC. So these, definitely, are being used in other applications, as well. There's a tool that's online, or should be online at some point late summer, early fall, and that incorporates some of the results that I've shown today, in addition to a lot more data from other AOGCMs and scenarios.

Ashley: Thank you. All right. I don't see any more questions. Dana, do you have any additional closing remarks?

Dana: Just want to thank everyone for participating today. I and any of the researchers who have presented would welcome any of your questions after the fact. Definitely get a hold of us and just a big thanks for showing up.

Ashley: Thanks, Dana. Shawn, did you have anything else to add?

Shawn: Just my thanks to the speakers for some wonderful presentations. Much appreciated.

Ashley: Excellent. Thank you, Shawn. I'd also like to thank our presenters, all of them, and also all of our participants.

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