Breaking Traditional Barriers to Model Climate Change and Land Use Impacts on Freshwater Mussels

Speakers:
Thomas Kwak, North Carolina Cooperative Fish & Wildlife Research Unit, NC State University

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Ashley Fortune: Good afternoon 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 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 Breaking Traditional Barriers to Model Climate Change and Land Use Impact on Freshwater Mussels. Our speaker today is Thomas Kwak, Leader at the USGS North Carolina Cooperative Fish and Wildlife Research Unit.

We'll introduce Tom in just a minute, but first I'd like to remind you of a few logistical details. Currently, all of your phones are on a global mute and they will continue to be so for the duration of the presentation so we can hear Tom. After the presentation, we'll open up the conference for questions, and I'll give you instructions at that time.

Everyone, please join me in welcoming Emily Fort, Data and Information Coordinator for the National Climate Change and Wildlife Science Center in Reston, Virginia. Emily, would you please introduce our speaker?

Emily Fort: I'll be happy to. Thanks, Ashley. We're really excited to have Tom here today to talk about his work. Tom Kwak has served as a leader of the North Carolina Cooperative Fish and

Wildlife Research Unit and Professor of biology at North Carolina State University since 1999. His interest and expertise are in the ecology and management of stream and river communities, with an emphasis on fish and fisheries. Much of his work has been in identifying physical and biotic influences on the ecological success of aquatic fauna at different spatial, temporal and organizational scales, and quantifying such relationships.

Tom mentors graduate and undergraduate students and has taught university courses in fishery techniques, ecology and management, including restoration ecology. He is active in a number of professional societies, especially the American Fishery Society and the Freshwater Mollusk Conservation Society.

We're very happy to have Tom here, and we're excited to learn. Thanks a lot.

Thomas Kwak: Thank you, Holly, Emily and Ashley, for all your help in setting this up. I think I'll switch to full screen. Thank you, everybody who's online listening and looking at the slides. The webinar today is very appropriate with all the budget cuts, and especially all the snowstorms throughout the Midwest and the northeast U.S. I'm glad you're all able to attend by phone from your home, or your office, or wherever you may be holed up through the snowstorm.

The talk I'm going to present today is about breaking traditional barriers to model climate change and land use impacts on freshwater mussels. The first barrier broken was to team up with a lot of different collaborators from around the country, spanning academia and agency.

It's very rare to have about 12 authors on the title slide, but in this case, everybody really contributed in different ways to the project to make it a success. I would argue that, by working together on a single funded project through the USGS and the South Atlantic LCC, that we were able to learn much more than any one of our groups could individually.

We have collaborators from USGS, North Carolina State University, the University of Wisconsin at La Crosse, the North Carolina Wildlife Resources Commission, U.S. Fish and Wildlife Service and the National Park Service.

I looked around in my book of quotes to sum this up with some very insightful quote, and didn't find one, so last year, when we started presenting our results around different conferences, the FMCS meeting in particular, we wrote our own quote. It was, "To achieve breakthrough scientific advances…it takes an army."

In this case we have an army with a lot of specialized expertise, including Byron Karns in mussel conservation. I study fisheries and river ecology. Greg Cope and Teresa Newton study mussel ecology and aquatic toxicology. Ryan Heise and Rob Nichols are state wildlife agency biologists that specialize in fish ecology and mussel ecology. Ashton Drew works on expert opinion, Bayesian Belief Networks, and has done a lot of the modeling for this.

Joe Daraio and Jerad Bales are hydrologists that model those components of our projects. Tom Augspurger has great insight with regard to how to apply these results to the policy and management arenas. Then, that's a lot of people with high-level degrees, and then we had three really ambitious, hard-working graduate students, Tamara Pandolfo, Jennifer Archambault, and Alissa Ganser. Tamara and Jennifer at NC State and Alissa is at UW-La Crosse.

What kind of barriers am I talking about when I'm talking about breaking them? I really mean spatial, organizational, political and conceptual barriers. We often sort of find our own little comfort zone to conduct research and to study conservation and ecology, and we tend to stay close to home in those studies, and developing them. We like to stay in our own states quite a bit, sometimes the research is funded by a state agency, and it makes sense to conduct the bulk of the research in that state.

But really, you might argue that we can learn more with broad spatial scales. Then we also went to school and we earned a degree in a specialized expertise, in a topic, and did even more specialized thesis research, and we like to stick in that general area, but you might argue to learn more by spreading out there into biology, genetics, or toxicology fields related to your specific expertise.

We study multiple taxa, and we might be resistant to some quantitative rigor, the modeling approaches or adaptive management or structured decision-making. We also tend to stay within our political comfort zone in academia in our state or federal agency, or working in an NGO. Finally, we are often stuck in our conceptual model, whether that be some niche in spatial, temporal, or organizational scale, or some other of the above categories I've been talking about.

Finally, we're going to present some modeling results today, and I think that we don't have to get so focused on, are these models predictive, are they realistic? Can we precisely predict the future with these models? I just don't think of them that way. I don't think that was the goal of our group. Our goal was to use these modeling exercises to learn about dynamic processes and general magnitudes and directions of impacts we might expect to see.

Thinking about conceptual scale, it can range from fine to broad, static to dynamic, simple to complex. In the spatial regime, that means working anywhere in-between from micro-habitats to landscape levels. For temporal, working in the current timescale, through the historic or static and dynamic modeling. Organizational, we might be most comfortable studying just a population, but expand that out to the community or the ecosystem.

I think we also learn more by looking at rate functions rather than static functions of a population. Things like production rate, growth rate, mortality, over time, might be more important than density or biomass of a population at any one time. Inarguably, if we want to look at broad-scale complex things like climate and landscape changes, we're going to have to delve into some of these more challenging aspects of research.

Global change is going on in virtually every country, every state. Stream ecologists have long known that what goes on up on the land affects what happens in the water. In particular, things that we do up on the watershed can change the water quality, the water temperature and the physical habitat for aquatic biota.

We're also greatly affected by climate change, of course, because things that happen up on the watershed can work synergistically to change temperature and habitat conditions in the stream environment.

The two primary aspects of climate change that we're interested in are changes in air temperature, which lead to changes in water temperature, as well as changes in precipitation and stream discharge. It's pretty undeniable, here around North Carolina, that we've had some serious climate change issues.

This is a photo screenshot that my collaborator Greg Cope took off his television, watching the local news in Raleigh, and found 158 degree microclimate in Louisburg. Needless to say, real estate prices have dropped. There are economic impacts to climate change.

The animal that we studied and modeled are freshwater mussels of the family Unionidae. Just for a little background, freshwater mussels are long-lived, benthic and sedentary animals. They are among the most rapidly-declining faunal groups globally, and to our knowledge 70 percent of North America's freshwater mussel species are classified as imperiled or extinct.

They're fragmented throughout the landscape in patchy distributions, which limits the ability for extirpated populations to recolonize.

We know from our lab work at North Carolina State University, published by Tamara Pandolfo in 2010, that some of the species of freshwater mussels are living very close to their upper thermal limits. We've observed over time through Heather Galbraith's research and some data I'll present to you today that the assemblage shifts seem to be to more thermally tolerant species over time.

Mussels are a great animal to study for looking at global change effects. They integrate so many aspects of the aquatic environment. They have a complex lifecycle that starts with the adults in the bottom of the stream or water body. They spawn and release glochidia.

Glochidia are a parasitic stage of freshwater mussels that are expelled toward fish hosts. They attach to their gills or fins where they'll incubate for several weeks and then drop off into the stream sediment.

This can serve certainly as a dispersal mechanism for a rather sessile organism. Mussels have very creative ways of attracting fish to them, including these lures that they develop with their mantles, that are pictured in some of the photos here.

We've been interested in this for a long time, and developed a collaborative project that we titled "Modeling the Responses of Imperiled Freshwater Mussels to Anthropogenically Induced Changes in Water Temperature, Habitat and Flow in the Streams of the Southeastern and Central United States."

Our primary objective was to apply new mussel risk threshold data in downscaled watershed and instream regional models, to forecast the species' responses to climate change and to begin to develop some adaptation strategies to mitigate those effects.

We're funded by two grants from the Department of the Interior. One from the USGS National Climate Change and Wildlife Science Center, and one from the Fish and Wildlife Service, through our South Atlantic Landscape Conservation Cooperative, here in Raleigh.

I'm just going to show you a little flow diagram about the conceptual way we initiated this research, and more or less the way our data and procedures have flown. First, we start off with general circulation models for climate predictions, and we downscaled them to the local watersheds we're studying.

Then we include some landscape dynamics, and some temperature dynamics. We use air temperature as a surrogate for stream temperature, and then model that relationship through regression. Then we develop some initial regional mussel occupancy models, where we will find any certain species of mussel at any certain time. Occupancy modeling also includes a detection probability, when you're working out in the field.

We used existing mussel thermal tolerance data that we had collected in previous research, and incorporated that into the occupancy models. Then, we went out into the field and our lab here in North Carolina and Wisconsin, and did some field measurements on mussel occurrence and their habitat suitabilities and relationships, and some lab measurements on thermal thresholds, looking at physiological and sublethal traits that might be affected by water temperature.

Then, we incorporate these results into refined regional mussel occupancy models, and develop regional climate change response projections. We can fine-tune these by looking at historical mussel trends, and doing some validity and sensitivity analyses.

We had research objectives in the laboratory, to determine mussel thermal tolerance and looking at sublethal behavioral traits, as well as acute mortality of different temperatures. We went in the field and we surveyed mussels and fish, and we measured various habitat parameters out in the field, at multiple scales, microhabitat, macrohabitat up on the watershed, and measured temperature instream and in the sediment where mussels occur.

Then we put some of this information together into modeling and analyses, by looking at historical community analyses in the Mississippi River, and developing hydrological and thermal models in the Tar River that would incorporate climate change and land use projections. Then we developed occupancy models, and looked at the factors that would affect occupancy of various mussels in a stream network, and brought this all together in the context of global change.

I'd like to start off by sharing some lab results, and I'm going to apologize that, really each of these categories could be a one-hour seminar. I'm going to give you some highlights of things that we found and thought you'd be interested in.

Alissa Ganser's thesis, at UW La Crosse, was to look at physiological traits of mussels rather than just acute lethality of different temperatures. She studied the effects on juvenile mussels of elevated water temperature, and looked at their survival, their heart rate and their growth rate, during 28-day exposures of juvenile mussels of three species.

In terms of survival, and let me just very briefly explain that an LT50 is the lethal temperature under which 50 percent of the test organisms die in exposures, and in this case, it's a 28-day exposure.

For example, with Lampsilis abrupta, 50 percent of the animals over a 28-day period died at temperatures of 27 degrees Celsius. The LT05 is a similar measure of lethality and is the temperature at which five percent of the organisms die during the 28-day exposure. We, of course, see that LT05's are more conservative lower numbers than the LT50s and, in general, an LT50 for these juveniles over 28 days range from 27 to 30 degrees.

Then we went on and looked at some of the physiological traits as related to temperature. Heart rate is generally considered a measure of metabolic rate of an animal, especially cold blooded animal, and we found significant temperature effects in two of the three species. If you think about poikilotherms, in theory, as the water temperature increases for them, their metabolism and heart rate should increase, but that's only up to a certain threshold of their optimum and then begins to decline after that.

We noticed that heart rate declining with temperature was an adaptation to conserve their energy under thermal stress conditions. These temperatures that Alissa was testing here are very commonly found in the Midwest and eastern U.S. streams where these mussels are abundant.

She then went on and looked at some adult physiology doing 21-day exposures in sand and fed the mussels daily with end points measured weekly and had high survival among the various temperatures but found significant temperature effects and oxygen consumption, nitrogen excretion, and the condition index at the end of the study for these animals.

Back here in North Carolina, Jennifer Archambault went to work in the lab and designed various exposure protocols to look at 24-hour acute exposures for Glochidia, the parasitic larval stage of mussels and 96-hour exposures for juveniles and survival worthy end points here. She also wanted to examine how we could make these laboratory exposures a little bit more ecologically realistic.

The ASTM standard test for looking at toxicity or thermal lethality in fresh water muscles is a water only test, meaning there's no substrate. Of course, mussels are really tied to the substrate.

We developed a test that we compared to wate- only tests with sediment in the bottom of the chamber and also to simulate low water and dewatered flow regime, we had a higher and a lower amount of water in the beakers in the sediment.

Jennifer also designed a very novel laboratory mesocosm to look at a vertical thermal gradient that very commonly occurs in a stream environment where the water in the substrate below the surface of the water is much cooler by several degrees than the surface water flowing over it. That might serve as a thermal refuge for freshwater mussels during times of high water temperature.

Jennifer designed this apparatus that's pictured here with an upper aqueous stratum where the temperature was kept rather warm and then a lower stratum where the temperature was held cooler by three to five degrees and an intermediate stratum of styrofoam that served as a transition zone that was about two degrees cooler than the surface water. We hypothesized that juvenile mussels might burrow down to the cooler water if given the opportunity.

These are some of Jennifer's thermal tolerance data. She conducted tests with water-only on Glochidia, water only on juveniles, low water with juveniles, and dewatered juveniles, with and without sediment. In general, she found a great deal of overlap among these tests and very similar results between life stages, the Glochidia versus the juveniles.

She found similar results between common and imperiled mussels species, similar results between Atlantic slope and interior basin species, and between her water only and her sediment tests, very similar results that were repeatable.

Between the low water and dewater tests to simulate changes in flow regime, she also found similar results. This was pretty surprising to us. She then went on to look at some sublethal measures of stress and looked at two behaviors, burrowing into the sediment as well as byssus production. Byssus is the material that mussels produce, particularly juveniles, as an attachment mechanism, and their byssus threads that are easily able to be seen in these tests that Jennifer was doing in the laboratory.

She found pretty distinct thermal effects of burrowing that fewer mussels burrowed at higher temperatures and fewer mussels produced byssus as well. That was true in low-water and dewatered treatments.

Here are the results for the byssus. We had with warming water temperatures for change per degree in byssus production of 18 percent to 35 percent among species and then the flow regime treatment, low-water or dewatered, also had a pretty significant effect in terms of byssus production. In the low water, we found less byssus production than we did in high water.

Then we went on to her vertical gradient experiments. To our surprise, the mussels did not burrow. We found similar effects of temperature in terms of low-water, dewatered, in terms of thermal grade, in terms of temperature lethality, in terms of byssus production, but no mussels burrowed to speak of beyond the top two and a half centimeters so we were unable to really elucidate that effect.

We were able to use this mesocosm to look at effects of temperature flow and acclamation. We're still not giving up on this approach and looking at other sediment sizes and such.

To summarize our lab findings, we found significant Glochidia and juvenile mortality at environmentally relevant temperatures. Juveniles and adults were physiologically sensitive to temperature in terms of physiological traits. Juveniles were behaviorally sensitive to temperature in terms of byssus production and burrowing and that lab testing approaches really yield similar results with sediment, without sediment, low-water, dewatered in terms of acute mortalities as well as the thermal gradient exposures.

Now, we're moving on to the field to collect some real data, empirical data, and we studied two different water sheds. First the St. Croix and upper Mississippi rivers in northern Wisconsin and Minnesota. There were eight sites and Teresa and Byron Karns led the field collections there. The upper Tar River Basin in North Carolina. It's a Piedmont and coastal plain warm water system.

The first thing we did was conduct mussel surveys at sites in the Tar River at 20 different sites. We spent at least six person hours minimum in snorkel and tactile surveys and then we went to the same stream reaches and in a 200-meter reach we sampled fish using two backpack electrofishers and used a pretty much standardized multi-pass procedure.

Of course, the significance of the fish in our studies is really to serve as mussel hosts and dispersal mechanisms. Many of these mussels are very specific in the host that they can use to incubate their Glochidia. We also collected in-stream habitat data, micro habitat measurements throughout the stream as well as macro habitat measurements of the reach.

Temperature was so important in this research to model changes in climate change that we developed what we thought was novel at the time, temperature recorders that would measure temperature with an eye button in the water column 10 centimeters above the epibenthic area, down in the sediment five centimeters below the sediment-water interface, and then even deeper than that, 15 centimeters.

We hypothesized that that would serve as a thermal buffer and we wanted to quantify those effects directly in the field.

About a year after we had developed these for our streams, we saw that they're commercially available now. They're not all that cheap to purchase, but we found the ones we built worked really very well.

As we suspected, we did find that sediment functions as a thermal buffer for mussels and especially the juveniles and these data that you're looking at are from the St. Croix and upper Miss in Wisconsin. We found temperatures usually varied down into the sediment by about three degrees Centigrade from that in the water column, but at one site in the Mississippi they varied by as much as seven degrees cooler.

We found similar results in the Tar River Basin in North Carolina, as well. The green is 15 centimeters below the sediment-water interface and you can see that during the summer warm months, the water's much cooler below the sediment. During fall, it becomes pretty similar and then during the winter, the water under the sediment is actually warmer. We found pretty similar magnitudes in the Tar River as to that in the upper Miss.

Then we wanted to do some modeling of all this and the first thing that we wanted to look at was a comparison of historical mussel assemblages in the upper Mississippi River relative to that of today. Teresa and Byron were fortunate to have some historical data and recent surveys, then, that they had conducted for comparison.

In general, we found the more thermally tolerant species became more abundant over time, and the thermally sensitive species tended to become less abundant in that river system.

This might be considered rather anecdotal, because there are a lot of confounding factors of course between 1920 and more recent surveys. But I do think that it's pretty indicative of a trend that we should be on the lookout for.

Then we developed some watershed models for the Tar River basin in North Carolina and we had 20 different sub watersheds that we modeled. We had temperature loggers in each of those, and all the field data that we collected in terms of instream habitat suitability parameters, as well as a good deal of information available through existing GIS layers. Joe Daraio and Jerad Bales are the hydrologists on the project. They were able to develop discharge models based on instream flow data that we collected, USGS gauges, the topography and geography of the watershed, as well as land use patterns, and geomorphology within the stream. What I'm showing you here are mean discharges over a multi-year period, and the dots are actual data, and the red lines are simulated data.

They did a pretty good job of being able to model the flow patterns with some pretty good precision. The next thing they did was to model temperature data. This is also observed and simulated, and had some pretty tight fitting models there as well. Of course, we were most interested in the warm months of the year in developing these models. These included historical data as well as the data that Tamara Pandolfo and others in North Carolina collected out in the field.

The next step in the temperature modeling, which was very important for looking at exceedance rates, was to develop hourly temperature models for different sites in the stream. Even I was very surprised myself at an hourly time scale, we were able to pretty well match simulated and observed patterns in the thermal environment, and Jerad and Joe validated these with an independent data set and the fit is really equally well with a new data set.

Now we had hourly temperature data in these streams during the warmest time of the year, and we could estimate the exceedances where fresh water mussels might be reaching or exceeding their thermal limits. Here's an hourly threshold exceedance frequency, so it's the number of times that a fraction of hours is exceeded in temperature.

If we start to the left, temperatures of 25 degrees, and these include observed and simulated are exceeded at a rate of anywhere between 15 and 25 percent. As you get warmer and warmer, less and less exceedance values. For example, the 30 degree centigrade exceedance value is just a percent or so, and that is the lethal temperature, the LT50 for juvenile mussels over a 28-day period.

You can see that, for example, the 28-day LTO5, or five percent of the exposed animals, are expected to suffer mortality is exceeded pretty frequently for glochidia juveniles there. So, let's look at some numbers related to this in terms of threshold exceedances directly applicable to the freshwater mussels.

The juvenile LT50 for 96 hours is about 34 degrees Celsius. That was not exceeded in any projections into the future up to the conditions for the year 2060. But if we look at the 32 degrees centigrade temperature, which is an LT50 for mussel glochidia over a 24-hour period, in the year 2030, we would expect that temperature to be exceeded 15 percent of the time.

In fact, that proportion doubles in 30-year increments later. Then even cooler temperatures, juvenile LT05s for 96 hours at 30 degrees are exceeded anywhere from 28 to 52 percent between 2030 and 2060. Glochidia LT05 is a very conservative 24-hour test shows exceedances 81 percent of the time in 2013, it's slightly higher in 2060.

So we can see that we're really not that far from having a pretty serious temperature effect if global climate predictions do materialize. The temperatures we're talking about between 30 and 35 are really not that unusual. This is a screenshot of real time water temperatures from July of 2012, and, of course, that was one of the hottest Julys in history.

But we see very common exceedances over 30 degrees and even over 35 degrees in the eastern and southern United States and Caribbean where a lot of these mussel species occur, especially some imperiled mussels.

The next thing we did was put all his information together in occupancy models. We did that for five species. This is part of Tamara Pandolfo's dissertation work at NC State. We looked at various covariates to model detection probabilities as well as actual occupancy, the presence or absence of a species at a particular site. We looked at things that are related to mussel dispersal, habitat, channel morphology, the fish hosts, things that might affect their food and water quality, like land use and cover, and, of course, temperature, because we're very interested in the climate change and temperature increases related to land use change.

We were not surprised by the model selection criteria and the covariates that were deemed the most parsimonious to explain detection probability. Those are typical things at the microhabitat level. The type of substrate in the habitat greatly affects our ability to detect the mussel species if it is in fact in the stream reach where we're searching, as well as the physical cover in the stream and the water velocity.

These came out really pretty much as expected. What maybe was not so expected was the occupancy probability covariate. Essentially, we found in various models for different species that all of these ecological functions and the parameters associated with them came out as significant explanatory variables for estimating occupancy probability of freshwater mussels.

It really does seem to be an integrated habitat suitability type of system that we're looking at here. It did, of course, include the thermal environment as well. Now that we have the occupancy models, we also had a number of species that are so rare in the environment, that are federally endangered and highly threatened such as the Tar River spinymussel, which is pictured here the left of the screen.

That kind of animal is very hard to go out and collect empirical data for and to model it that way. Ashton Drew is our expert modeler for eliciting expert knowledge and incorporating that into different modeling scenarios. She had conducted several design workshops with local mussel experts and national experts and did some data collection in the field as well and developed prediction elicitations and then developed a Bayesian Belief Network.

We then went on, finally, to verify and validate those data and those projections on what is suitable habitat for imperiled species like the Tar River spinymussel. So, it varies. This model incorporates both qualitative knowledge from the experts as well as quantitative knowledge that we then went out into the field to collect and validate.

Finally, really the ultimate end product for our agencies, is a decision support tool. This includes data that from the landscape level, GIS type data, and including occupancy data, and then field data that we collected as well, including occupancy data in terms of mussels occurring there.

The GIS data is the probability of suitable habitat being at any one site in a drainage network. When we put all this information together, we can come up with various management and conservation scenarios ranging from no-action, restoring habitat, translocating or reintroducing populations, releasing captive bred mussels, and, in the situation where the habitat is already occupied, protection strategies.

I think this is going to be a very useful tool. One of our objectives is that it might become a model that could apply in other areas. Right now Ashton is finalizing this and we're doing some, still this summer, some validation field surveys to refine those models.

Back to all of our research objectives. Finally, we want to put this together into a synthesis toward global change. We've got several papers right now submitted to journals and hope to bring it all together in one large summary paper. So were we successful in breaking traditional barriers? I think in this case, I'd like to say we were. We did really abandon those professional comfort zones.

We went outside of our local state and region, and we spanned between the upper Midwest and the eastern seaboard. We included modeling and empirical information beyond just ecology and conservation, including animal biology, stream hydrology, and aquatic toxicology. We looked at multiple taxa, multiple life stages. Certainly have the quantitative rigor that we sought using Bayesian Belief Networks, adaptive resource management, and structured decision making.

The politics, I thought, was pretty good. We spanned academia and agencies both at state and federal level and developed conceptual models that integrate among scales I think, and really do believe that so far we've learned a lot from these modeling exercises.

We hope to continue this line of research and expand it and hopefully, develop some models for other that could be applied elsewhere in the US. With that, I'd be glad to address any questions that I might but also many of the collaborators whose work we've highlighted here are online as well.

If there's a specific question that they might address better than me then they'll be online and be able to do that. Thank you all for your attention. Thanks again to Holly, Emily and Ashley for hosting and be glad to answer any questions or entertain some discussion.

Ashley: Excellent. Thank you so much Tom. Everyone, if you'd like to ask a question, we already are getting some in the chat box. You can either use the chat box or you can press the raised hand icon that's located between the participant list and the chat box. Once you press that I will see your hand raised. Actually, Tom, can you bring us back by pressing the stop button to the home page. The stop button.

Thomas: I think I just did that. You're not seeing it? [pause]

Ashley: No. Are you in full screen right now?

Thomas: No. Let me go back to full screen and try.

Ashley: Perfect.

Thomas: Did that do it? OK.

Ashley: Yes. Thank you very much. It might have just been my computer. [laughs] If you want to ask a question you can press the raise hand icon that's located between the participant list and the chat box. I will see your hand raised. I will call on you by name. Then you are going to want to take off the mute off your own phone, if it's on, and then you're also going to want to unmute the global mute by pressing *6. On to the first question from Matt Patterson. He says, "You mentioned strategies for mitigation. Are there any ideas out there on how to mitigate for climate change when it comes to mussels?"

Thomas: I'll answer that and then I'll open it up to my collaborators. But, in general, we find land use and things that we do on the watershed, how we manage the land to really be synergistic with climate change. That as we create more urbanized watersheds, as we have direct runoff going in, as we clear the forest canopy along streams, that really has a general warming effect on our surface waters. While in a regional or a local scale, we don't have much of an opportunity to control climate change, or any warming, but we do have the chance to do some land use planning that could have a mitigating effect. That's the primary approach that comes to mind to me. I did, with a colleague Jim Peterson, some modeling of a Midwestern river, where we showed that if we returned the land use patterns of the watershed of the Kankakee River in Illinois to their historical state, that we could pretty much mitigate totally for climate change to year 2060 or so.

Anybody else, Joe or anybody else, a comment on that? Teresa? Greg?

[silence]

Thomas: I guess they're letting me handle that one. Thanks for that question.

Ashley: Ok, do we have any more questions? Yes. From Daelyn. I hope I pronounced your name right. It says, "You referenced 2030 and 2060 as predictions for climate change temperatures, changes in time-frame. Are these IPCC data you used or something else? From your perspective, what are the best models for future prediction?"

Thomas: I could answer that question pretty generally. Then probably Joe Daraio or Tamara Pandolfo might be able to answer more specifically. Yeah, those are IPCC data, but there are other general circulation models available that recently have been downscaled. USGS has just put together a big effort through Katherine Hayhoe and the wildlife and climate science centers in Reston, to downscale many of those circulation models for the entire country. 2030 and 2060 were just various endpoints for IPCC data. Then I'm going to ask Joe Daraio if he has anything to add to that. Joe, are you out there?

Joe Daraio: Yeah, I'm here. We actually did use the downscaled data from Hayhoe. Those are downscale general circulation models. One of the issues with those models is they don't tend to simulate extreme events very well. There are other options, and there are other options to use regionally downscaled models, which I don't know what's available for the southeast. But, right now, I'm in New Jersey now, and there are some models, regionally downscaled models, which tend to be a little bit more accurate when it comes to extreme events. One aspect that we did not include in our models was specifically extreme events. The analysis could be extended for an increase in frequency of extreme events which is a likely consequence of climate change, that we get more larger events and have more rainfall.

A greater proportion of the rainfall would come from heavy events which would have an impact on stream flow in particular but also extreme temperature. We did not do that but there are data available and there are models that can do that.

Thomas: Hopefully, you get that modeled before the next Hurricane Sandy like event.

Joe: Yes. [laughs] I'm working on it now, actually.

Thomas: Is there another question, Ashley?

Ashley: Yes. There's one from Dan Hua, "I'd like to know if you tried other spatial models to do analysis?"

Thomas: Other spatial models? Tamara or Joe, any ideas on that?

Joe: For what, for the...?

Thomas: The hydrologic modeling, or the occupancy modeling, Dan? What are you thinking about?

Ashley: He says MaxEnt and RS. MaxEnt.

Thomas: Joe, you did not use MaxEnt at all.

Joe: No.

Thomas: Ashton, are you on there? I think he's talking about the decision support tools, also.

Ashton Drew: Hi, this is Ashton. I am on. I did not use MaxEnt. We don't have enough presence data for it. There's only three sites, really, with the Tar River spinymussel.

Thomas: Yeah. One difficulty that we had is...Our emphasis is on the imperiled mussels. They're variably less abundant than the more common mussels. For example, Tamara had occupancy information on at least 20 sites in the sub watersheds in the Tar River Basin. Some of the species like the Dwarf wedgemussel are in certain habitats, whereas the Tar Spiny River is so rare that you might collect one a year if you scour the river very well. Then we have really common species, like Elliptio complanata, that were at every site. So it's not a very interesting occupancy model, when the mussel is pretty much ubiquitous through your watershed. Any other questions?

Ashley: Dan, did we answer your questions? Did they hit on it? While we're waiting for Dan to respond, we have one from Theresa Thom, who says, "Have you or will you consider examining genetic variability of mussel species and populations, as a next step in evaluating resilience of various mussel species to various impacts from climate change?"

Thomas: I think that's just a great suggestion. I collaborate pretty frequently with Greg Cope when we do mussel work, because that's really his expertise. We've been talking to a geneticist here at NC State, Martha Ryskin, about using various genetic tools to sort of get it. It's just that thing, resiliency and effective population sizes, and things like that. In fact, we're interested in doing some reciprocal transplant experiments as well, where we would use a common genetic stock. Yeah, I think that's a great suggestion. I'll bet a dollar that other people are already doing it, and that's one of the things we're sort of seeking funding to do, as a next step.

Teresa, anything over in Wisconsin, in terms of the genetics?

Teresa Newton: Not at this time, although we also have been putting a few feelers out, to see what might be out there, and what the interest is.

Thomas: Yeah, I think the molecular tools that have become less expensive, less costly, and more precise to use are just opening up all kinds of possibilities for people studying conservation of imperiled species.

Ashley: Thank you. We have another question from Matt Patterson, who says, "Do you know if there are thermal tolerances for the Glochidial attachment to the fish host?"

Thomas: I'm going to bet Greg Cope or Tamara Pandolfo will know that, because they're going to have to say what happens to Glochidia that are attached to a fish, and then their thermal tolerance is reached. Do Greg or Tamara or Teresa have an answer to that? That's a great question, and we did not specifically study Glochidia on fish, but I bet those folks are well-read enough to answer that question. Greg, come on.

Greg Cope: Tamara's on board.

Tamara Pandolfo: As we said we didn't do that ourselves for this project, but I think there's a couple of references out there where that's been done. I can't remember the citations exactly, but maybe out of Chris Barnhart's lab or [inaudible] lab, I think they might have done a few pieces of work. I don't think it's been done extensively, but there's a little bit of information out there.

Greg: That is correct. It's not very extensive. In fact, the life stage of Glochidia, once it's encycted on the host fish...There's very little information for thermal sensitivity, but in particular, very little information on toxicant and other kinds of exposures that might happen while the Glochidia are attached or encycted on tissues of the host fish. So I think it's a very good question and one that deserves a lot more attention.

Thomas: Related to that, Tamara, Greg and I just published a paper in Walkerana, the journal of the Freshwater Mollusk Conservation Society, that compared thermal tolerances of freshwater mussel species to their specific fish hosts. We found, in general, that the thermal tolerance of the fish host can be more of a liability, more stenothermic, than that of the mussel itself. So that further adds another sort of complex constraint, because of their parasitic lifecycle. [pause] Anything else, Ashley?

Ashley: I'm just scrolling through. They said...You just answered it...If the decision support tool is available, or will it be? I think you just said that.

Thomas: Ashton, do you want to talk about that? Actually, that is still being developed. Our climate change grant from the USGS has just terminated, and we have some products that will soon be available from that. But our funding from the Fish and Wildlife Service, South Atlantic LCC, is still active and we're sort of toward the tail end of that. Ashton, any projections when that tool might be available as a model?

Ashton: I think our final products are due in December, the end of the year. Is that correct?

Thomas: Yeah. I guess the funding is up in September, and December's the final product.

Ashton: It'll be whatever has to go through review and everything, as well. Which I've learned takes a while with USGS stuff.

Thomas: We'll do some fundamental science practices review on that. I would say next spring or so, Ashton?

Ashton: Yeah, sure. However long that review would take. I'm assuming what we'll have to turn in, in December, is our final product, and working towards that goal.

Thomas: Very good.

Ashton: To make it clear, it won't be a pretty GUI interface decision support tool. It would just be the...Having developed the method for how it works, and sort of run it once.

Thomas: But there's no reason people couldn't pick that up and in other areas, and use it as a model?

Ashton: That's the idea.

Thomas: To develop their own model, I guess is what I'm trying to say.

Ashton: Correct. It's being developed as a sort of general approach, using the Tar River spinymussel as an example, but where the variables that are included are things that we expect mussels in general to...Like when you showed the occupancy. The list of variables that were in the occupancy and detection models, those kinds of things. Those are the sorts of things that might matter to various mussel species, but matter to them differently. The threshold levels could be changed for various components of the model. The specific target level, if you were looking for the temperature target. Or the substrate targets could be changed. But you'd be inputting the same spatial data, assuming you had it.

We've tried to go mostly with national data products feeding in, so that those would be things that other people would have access to.

Thomas: Thanks, Ashton. Ashley, how long do we have this line?

Ashley: We have it for another half an hour. We do have one more question, from Leroy Koch. Leroy, you can ask your question.

Leroy Koch: Can you hear me? This is Leroy.

Thomas: Yes.

Ashley: Yes.

Leroy: Good. I couldn't figure out how to do the chat thing, so I thought I'd better raise my hand. This is an extremely interesting presentation. I really appreciate this. There's all kinds of things that I'm thinking about. On a real practical basis, I'm thinking that, thermal tolerances with various species of mussels, we're probably already maybe seeing some of this. I don't really have a question per se, other than just some comments. At least here in Kentucky in the Green River, which is one of our best rivers in the state for mussel diversity and all that. It seems to be also an area that is very karsty and has a lot of springs that enter into the river, which, I think could be assumed, help keep the temperatures a little bit cooler, perhaps.

I was wondering if there was any folks out there that are looking at, from a practical standpoint of managing mussels and keeping certain species, finding the best rivers and streams in which we can do augmentations and transplantations and all that.

Do we need to start thinking about picking out areas in the country, rivers that are maybe going to be better suited to, and less apt to be affected by temperature change, because of maybe influences like springs and upwellings or whatever. It's kind of interesting.

I know some work that we're doing up in Ohio in Killbuck Creek with the purple cat's paw mussel, which is the only place that they're known to occur at this point in time. We've been having some search efforts for that species since 2006, and last year was the most successful in which we found some females and males.

But it just so happened that one of the areas in which most of those were being observed was in an area where the mussel searcher was noticing some real cool water coming up out of the river bottom. I just wonder if anybody else has been noticing around the country, where there seems to be maybe a cooler spot in the river in which some of these mussels are perhaps still clinging on.

Just, in this particular case in Killbuck, it's one of the Epioblasmas which of course are almost all extinct. But, let's open it up for discussion, see if anybody has anything to say. Just an observation more than anything else.

Thomas: Leroy, I think that's a great observation. I think it, I wouldn't say it's common, but I think other people have observed that; that groundwater inputs are extremely important for, especially it seems like, the imperiled mussels. I think that's true for the Tar spiny, and it's even more important in sort of karst geology areas, like you're talking about. But it's important also for us here in the Piedmont and the coastal plain.

Joe had talked about doing some specific modeling that might get at that, like looking at gradients and stream incision and what might be sort of some hot spots for groundwater upwelling or seeps.

With regard to your other question, and I'll let Joe talk in a second, I think identifying potential refugia is a real important application of the kind of research we're doing here. But, we're generally working within a drainage area, within a watershed and river basin.

I wonder if the day is going to come where we might have to look outside the native river basin to establish populations, rather than lose species altogether or bringing them into captivity alone.

It's a big, interesting question. Joe, do you have...I just remember a conversation with you when we were talking about modeling upwelling and groundwater and that there were some landscape variables that you might be able to relate to it. Is that true?

Joe: Yeah, it is. Actually, it's one of the things that I'm working. One of my proposals that I have out is to look out, to get some temperatures deeper than what we had in the Tar River for temperature loggers, to see if we've got incoming groundwater from below. But it's really, really important for string temperature model. I think that finding areas that are more stable because of groundwater influx might be a good way to actually maybe find better habitats. I had been thinking about using the modeling to maybe be able to locate areas with more stable temperatures or that might be better habitats for some species.

Of course, the stuff that I'm doing is not, I'm not a biologist so it's all the modeling. But I do think there's a potential for modeling applications with that, in that area.

Greg: There is that potential. Leroy, this is Greg. I think you're right on target with that question and that point. I think it was borne out here, especially for the observations of the experts that Ashton interviewed for the Tar River spinymussel work is that where they seem to be hanging on are these areas of groundwater interaction in the stream bed, and providing these localized refugia. From Joe's perspective, I think being able to detect those and model those. There are tools that we know are available and had some comments and discussions with the USGS water science folks and being able to lay down and actually quantify within the stream bed these areas of groundwater influence.

I think that is a really good point and one that we probably ought to pay more attention to in the future.

Teresa: Leroy, this is Teresa. We've done that for the upper Miss. We've actually looked at groundwater inputs and overlaid that with distributional maps and we found high degree of concurrence between where we see the dense and diverse assemblages of mussels, even in the upper Miss, coincides nicely with where we see the groundwater inputs as well.

The other thing people have to remember is mussels do have some behavioral adaptations in terms of vertical and horizontal movement to try to seek some of these thermal refugia, even at a microscale.

Leroy: I appreciate that conversation. It opens up all kinds of questions on management as to how we should select or try to work towards protecting and being able to manage areas that maybe we'll, in the future, see an increased, important role in maintaining certain species of mussels. Where, if we can't spread them out everywhere, we may end up having them in just a few select areas where the temperatures are more stable. Lots of ways to look at this. It's real interesting.

Ashley: Then just to add on, Shane Hanlon said, "We have actually noticed abnormally cold water conditions in the terraced influent streams during drought years, even with high ambient air temperatures."

Leroy: Thank you.

Thomas: That's right. In karst areas, I think groundwater and surface water are really not too separate resources to be managed that way. It's all more or less intertwined.

Ashley: Could you just repeat that last part? There was some background noise.

Thomas: In karst areas of the country, where the water can percolate between the groundwater and the surface water pretty freely...It seems like in the U.S., we've always thought about managing groundwater and managing surface waters, but that doesn't hold true very much in karst areas. I spent some time in the Ozarks of Arkansas, and much of the groundwater there, that people used to use for drinking water wells, is polluted from a lot of the agricultural pollution, from chicken industry and confined animal operations.

It's really not the best way to think of managing your water resources, in terms of two separate pools of water, especially in karst areas where there's a lot of interchange.

Ashley: Thank you. Dan was able to get back, and he's just wondering if you've ever tried the MaxEnt model.

Thomas: Ashton, are you still on? We have not, but why not, Ashton?

Ashton: I'm still on. We've used MaxEnt in our research group for other projects, but it's usually with presence-only data. Again, we don't have enough data points to really use MaxEnt for the super-imperiled mussels. The sites are so different. It was even the same when we had experts to get it, that it's not...If you only have three sites, you might have three different sediment types. One site appears to have groundwater and one site appears not to. One site appears to have shelter from coarse, woody debris, where another has it from rocks.

They're at so few sites. You need to have some of those correlations for MaxEnt to work well. [laughs]

Thomas: Thanks, Ashton. Are there any more, Ashley?

Ashley: I'm not seeing any more. Do you have any closing remarks?

Thomas: I don't. Nothing in particular, other than I'd like to thank everybody for participating, and look forward to others working in this line of research. Hopefully, we'll be doing some more, and have some publications available. You can check our respective websites once in a while, as well as the National Wildlife and Climate Change website for this project, for products as they become available. Just thanks to everybody, and to my collaborators as well.

Ashley: Excellent. Thank you very much, Tom. Pretty interesting discussion surrounding this. A recording of this broadcast will be posted on the USGS National Climate Change and Wildlife Science Center website. It's shown on the screen there, in the chat box. All of them are there, actually, all of our previous webinars, as well. If you missed one, it's a great resource to go back to.

Our next webinar will be on April 11th at 2:30 PM Eastern. This will be part one of a two-part series. We have several speakers. Dr. Joanna Whittier, University of Missouri; Craig Paukert, Missouri Cooperative Fish and Wildlife Research Unit; and Tyrell Deweber, Penn State University.

They will be presenting on “Fish Habitat and Climate Change: Implications for the Desert Southwest and Midwestern Smallmouth bass and Eastern Brook trout”.

Please stay tuned for an announcement and thank you again all for your participation.

Thomas: Sounds great, Ashley. Thank you.