USACE ERDC

Moderator: Julie Marcy
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Julie Marcy: This is Julie Marcy. I am with the Engineer Research and Development Center's Environmental Lab in Vicksburg, Mississippi. I'd like to welcome everyone to our Webinar series. The series is co-sponsored by the Aquatic Nuisance Species Research Program and the Army Corps of Engineers Invasive Species Leadership Team.

The webinars are designed to address topics of concern on invasive species issues, and we record and archive the meetings for posting on our Natural Resources Management Gateway.

Just a few reminders before we begin today. When we are in the open line sessions, like right now, and then when we get to the question-and-answer session, if you would keep your phones on mute, that would be very helpful.

When we begin the actual presentation, I am going to apply a global mute to everyone, and that will eliminate some of the background noise and enable us to have a better recording for the session.

When it is time for questions, I will open the lines, and – but if you have activated the mute button on your individual phone, you may need to unmute it so that we can hear you. Or, if you prefer, you can use the little Chat feature in the WebEx program to send questions in that way.

If you are having trouble being heard at any time, feel free to use the little raise-your-hand icon, or you can send me, Julie Marcy, a message if there's something that I can do to help you out.

Also, if – as you're signing in – if your organization is not apparent by the name you signed in with, if you could send me, Julie Marcy, a Chat to add that, that would be very helpful in helping us maintain a list of participants.

Lastly, if you are calling in with a group, if you would also indicate that there are, say, four people in your group from X Organization that would be helpful.

I see we have folks calling in from ERDC, from across the Corps, and some of our State partners in Wisconsin and elsewhere. Good to have such a diverse group with us. I think we will have a few more folks logging in, because we had about 22 folks that accepted the invitation.

Let's go ahead and get to the main topic for today. Our speaker is going to be Todd Swannack. Dr. Todd Swannack is the Team Lead for the Integrated Ecological Modeling Team at the ERDC Environmental Lab.

Julie Marcy: Todd develops quantitative ecological models to evaluate impacts and benefits of Civil Works and military projects on ecological communities. Todd and his team develop models for endangered species, invasive species, landscape changes, thin-layer placement of dredge material and other engineering-with-nature projects.

His team's work with invasive zebra mussels was funded principally by the Aquatic Nuisance Species Research Program, and it included developing an integrated, spatially-explicit simulation model that can simulate how human-

mediated transport impacts the population dynamics and dispersal of the species.

Todd's bio is posted on the Natural Resources Management Gateway, and after our presentation, we'll be following up with posting a recording of the presentation, a PDF of Todd's PowerPoint, and then a little bit later, since we need some time for edits, we'll also have a written transcript of the presentation.

Todd, we're really glad to have you with us today, and I'm going to go ahead and give you presenter rights, and if you can Star-6 your phone and go to Shared Desktop, we'll begin. Okay. I can hear you, so great. Cool. All right. If you can share your screen, or share your screen with us.

Dr. Todd Swannack: Thank you very much for taking the time out of your day to listen to some of the research we've been doing on invasive species. Just a little bit of background that to continue on with what Julie was saying.

I'm the Lead for the Integrated Ecological Modeling Team of the ERDC. And, we had an opportunity to work on developing some models for zebra mussels, which are a hyper-invasive species.

The zebra mussels, they were introduced via the Great Lakes, and they've been spreading across the country rapidly since the early '90s. And, you can see that in these maps--the bottom left corner of the map is the current distribution of zebra mussels. One of the reasons they're really terrible is they really can reduce native biodiversity. So, they can reduce local diversity, but they can also just cause a ton of structural damage.

Once these things get established into a water body, they're almost impossible to get out. You can kind of see in these pictures some of the issues that occur when you get zebra mussels. In the picture on the right— that's a pipe that's been clogged up with a community of zebra mussels.

Then on the left is – the left bottom picture is a picture of a lake that has receded, but it is infested with the zebra mussel. The estimates from this picture – about a million zebra mussels in just within the picture area that you can see.

They take over everything, and they can do a lot of damage both structurally, but also they can – they're really, really efficient filter feeders, and so they can filter all the nutrients out of the water, which can cause – which causes them to outcompete any of the other native mussel species.

And then on the right-hand bottom, you can see that they actually can – they'll attach to anything that has a hard shell, whether that's human-made or, like, the carapace of a crayfish. Probably not too fun to walk around with all that stuff.

One of the kickers is the spread mechanisms are poorly understood because they're relatively complex. They can be – they can spread naturally through water bodies — particularly in dammed rivers they can be released when the dam – when they're doing the releases. They can go downstream that way.

But, they can also be introduced and transported via humans. They have a complex life cycle. It's not as complex as the fresh-water mussels that have fish hosts – intermediate fish hosts – where they attach – the larvae attach to the fish gills, but so, the way that these things reproduce is they broadcast spawn, and then they release larvae into the water.

They stay as a larval form for a while, and during that time period, they're pelagic. They actually move with the flow of water, much like oysters do in the ocean. They just kind of move back and forth depending on where the flow of the water goes.

Once they've reached a certain age, they will descend and attach to anything hard with their byssal threads, and they will lock onto any kind of substrates – hard substrates, just like I showed you in the previous picture.

This makes them really tricky to manage against, or manage for. The kicker with this is that we, collectively, didn't know much about this species, because it's invasive. And it proliferated so quickly that the regional-based approaches that we were using to model this stuff really became antiquated before they should have, because the zebra mussel just spread really fast.

And so a lot of the studies that have been done — and there have been some fantastic studies done on habitat requirements — but they've been at the regional scale where they're very detailed at a regional level, or at a national scale where they're relatively coarse.

They've focused – a lot of these studies have focused on lentic environments, like lakes and impoundments and ponds. But, little is known about how the zebra mussels — and particularly their larval forms — actually react to flowing rivers, and also, the larvae are really sensitive. They're soft tissue, and one of the things we were really curious about is what's the effect of turbulence on the larval structures?

One of our hypotheses was to figure out or — well, our hypothesis was that maybe if the water was turbulent enough it would rip apart the zebra mussel

larvae and could actually help prevent them from distributing themselves in new areas.

The lake-to-lake connectivity and distribution is, in upstream spread, is primarily facilitated by humans. And so, one of the reasons that this happens is that people will go boating, and zebra mussels will attach to their boats, and then they will go from Lake A to Lake B — maybe because it's a bigger lake or the next lake, Lake B is not as crowded, or maybe there's better fish there, or maybe you just want to go somewhere new.

The kicker with this is these zebra mussels, they can actually – the adults can detach from their substrate when, unlike oysters and other stuff that's permanently sedentary, these things can detach, and they'll attach on boats. The larvae can stick to the boats.

But they live for – they can live for a while out of water. On the right hand side of this slide, you can see the recommended quarantine times when drying out a boat.

As the temperature increases in the summer times, that should help kill them, but one of the ways that these critters have spread is just before invasive species awareness hit critical mass, it – people weren't cleaning off their boats.

For those of you that are calling in from the Minnesota-Wisconsin regions, there are signs all over the place to talk about cleaning your boats. There are stations where, you know, there are people that will check your boats.

I'm actually stationed out of Austin, Texas, and we have some zebra mussels that are making their way down to us. They're about 100 miles north of us now. Checking boats in Texas is a foreign concept.

Now that there are billboards up on the Interstates about zebra mussels and cleaning your boats, which is the first time an invasive species has been addressed in a public manner like this.

You have all of these factors that contribute to a relatively complex dispersal pattern. I'm going to talk about some work we collaborated on with the University of Minnesota, the St. Anthony Falls Lab, with the St. Paul District (Van Kelner), with the St. Croix River Watershed Research Station, and then – and this is all a modeling study.

We did it in the St. Croix River. That was our case study area. And we chose this because there's a lot going on up there. The distribution of zebra mussels is pretty well-known. And there are a lot of lakes and water bodies that we can use to kind of test our ideas from the modeling standpoint.

So we knew that the zebra mussels – we understand their life history, and but we know that their dispersal can be driven by hydrodynamics. So, they can go downstream with the flow of the water.

But, they can also go lake-to-lake. We knew we needed some kind of hydrodynamic model to capture that aspect. We knew we needed a life history model – a population dynamics model – because since these things can live for a while when they're out of water, and it takes them a while to mature and, you know, broadcast spawn, we needed a life history model.

We incorporated – we used an integrated modeling approach to incorporate the hydrodynamics, the life history, the habitat suitability of lakes, and then a boater-behavior model that looked at potential boater (beat) mediated transport.

I'm going to kind of walk through each of these, and show you kind of what we've done, and the technology that is available now and that we're really excited about showing off.

We developed this conceptual framework for how we were going to model it. I'll show a couple of different pictures of this, but basically if you look at the right-hand side, you have some lakes that may or may not be connected. They can be transported — the red dotted line is supposed to represent a boat going from the top lake where there's an asterisk and down to the bottom.

But then, you also have river-mediated transport. One of the things that was really missing was how do juveniles respond to turbulence? I'll talk about a cooperative experiment we did with the St. Anthony Falls Lab at University of Minnesota.

So, this is our conceptual model. We knew we needed a boater-behavior model that took into account how people move between lakes. We needed a hydrodynamic model, and we didn't get super-fine scale because the computational time was really intense, but it had water quality and temperature for the St. Croix River Watershed, and this fed into a larval transport model.

And then, we had a mussel dynamics life history model that simulated the natural history of the mussel populations and gave us an idea of when they would spawn and basically, how many juveniles they would produce.

The first thing we did, we – as we were going through the literature, we realized that we needed to address the larval dispersal. It's not well known, and particularly with this hypothesis that maybe turbulence could tear these suckers apart, the — you know, we really wanted to get some field experiments or some lab experiments to test some of this stuff.

And St. Anthony Falls, we set up a collaborative agreement with them, and they worked in the St. Paul District to get zebra mussel veligers. Then they did some experiments that would quantify how turbulence impacts the veliger species.

Here's some results from the experiment that the University of Minnesota did. These results are – they just came out two weeks ago, and we're really excited about this.

They had this box that had some speakers – underwater speakers in it. And they can vary the acoustics so that they can create turbulent waves inside the tank. It's really cool. And, they can measure the turbulence.

So, they would put the flow — and they had a flow going across the tank. And then they would get the amplitude and basically, they would bass these suckers out to see what tore them apart. And, you can see the sound waves on the flow velocity in the black and white picture to figure out what the – what turbulence actually would be detrimental to their survival.

Mortality actually goes up if you look at this right hand corner. Mortality is actually going up as the amplitude or the turbulence increases.

This is positive, in terms of thinking long-term for management. This is a basic research level right now. But, the results are promising in that, maybe down the road we can figure out a strategy to – for the zebra mussels in the river, particularly the larval stages to, you know, maybe we can time releases to create more turbulent flow to reduce zebra mussel dispersal.

The main focus of this, then, is this integrated modeling approach. As Julie said, I'm a modeler, so I'm going to spend some time talking about that. And so, Julie, can you still see me?

Julie Marcy: Yes. It's on the Turbulence Experiment slide.

Dr. Todd Swannack: No, it looks like it just crashed.

Julie Marcy: Okay. You want to stop sharing your desktop?

Dr. Todd Swannack: It's not even — yes. I don't have it. It kicked me out of the meeting.

Dr. Todd Swannack: So, yes. If you could go to the next slide in the…

Julie Marcy: Let me get your slide. Now I'm on the Turbulence Experiment. Do you want the next slide?

Dr. Todd Swannack: Okay. So just go to the next slide please.

Julie Marcy: Okay. Integrated Modeling Approach.

Dr. Todd Swannack: Okay. Perfect.

So, we use these turbulence experiments to serve as a proxy for parameterizing our data set for our models. I'm going to kind of walk through the models, and talk about how we integrated them, and talk about kind of what our results are. And talk through, you know, where we need to go next with this.

The picture on the left is a Google Earth image of the St. Croix River Watershed that's highlighted in yellow. And the red are areas where zebra mussels have been found. And the blue are lakes that are within 50 miles of the St. Croix River Watershed.

And for the purposes of this proof-of-concept model, I'm going to just talk about the area within the yellow border – just the St. Croix River Watershed. So, we can actually see some results.

The hydrodynamic model — we used a SWAT model of the St. Croix River Watershed to get the flow and temperature. We used a boater model that calculated the attractiveness of each water body to boaters. And we would simulate boater movement. I'm going to go through this and show some details as we go through.

We used this model to determine if boaters introduce zebra mussels. We had a zebra mussel population dynamics model that calculates if zebra mussels can survive in a new habitat based on the suitability. We accumulated zebra mussels over time and simulated the life history of the species to see how often they would spawn, et cetera.

So oh, next slide, please.

The hydrodynamic model, we needed something at the watershed level that would run in a reasonable timeframe, so we used the SWAT model. And, it had already been developed by the St. Croix Watershed Research Station, which was fantastic. And so, this modeled the flow and hydrodynamics in the Watershed. We used the velocities and turbulence values to determine larval survival.

In addition, where we are right now, because the turbulence values — that research just finished up — so we're in the process of incorporating those results into our equations for the modeling. But we used a surrogate to just assume, after turbulence at a certain value, the zebra mussels' larvae wouldn't survive.

The other thing that this was really crucial for was it helped us get residence times. And, it provided connectivity from lake to lake. So lakes that are on the – within the Watershed – that are connected via tributaries or the main stem, it provided us an idea of how long it would take water to reach between the lakes, and so we could actually figure out if zebra mussels would make it down based on a certain spawning event.

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So – and to me, this next part is the coolest. We then developed a boater-behavior model, and if you've been in areas with invasive species, particularly the stuff that sticks to boats, you'll see something like this sign that says, "Look for mussels here."

And because these critters can – they'll stick to anything. They can get on your boat. And it only takes a couple to colonize a new area. And if you have a boy and girl zebra mussel, they'll zebra mussel it up in the water, and they

will start to really wreak havoc within your watershed – within your water body.

We were after was a tool that could be used by Natural Resource managers and scientists that was relatively simple but had a high degree of accuracy.

We knew that one of the deals when you use integrated modeling approaches is you're plugging together a bunch of different models, and sometimes if you get too complex, it can take forever for it to run. And then, it defeats the purpose of having some kind of proactive approach.

We developed what's called a "constrained gravity model" to determine the probability that a boater would move from one lake to another given lake.

This approach is really neat. It's based on the physics of two celestial bodies – the forces of gravity between the two celestial bodies. So, like Jupiter and the Earth, they stay apart based because of the forces of gravity. So that's actually what this does, is it just mimics that, and but it adds a couple of factors in there that determine the attractiveness of the water bodies to each other, based on the boaters' perspective.

In this model, we calculated the distance between the water bodies. So, that was one level of – that was one factor. And that's actually based straight on the physics of gravity.

And then we had a factor that attracts boaters. In this case, we used lake size. The idea being that if the lake was really big, people would want to go there.

We had some parameters in there that just assured all the boats moved, rather than stay in the same place.

And then we figured out a probability of that if a boat was in a lake with zebra mussels, what's the probability that it transferred those zebra mussels from Lake A to Lake B, or Lake A to Lake Z, or like Lake A to Lake 1012.

We looked at all that and then — next slide — and then we came up with a habitat suitability model that was developed for the St. Paul District — and Dan Kelner helped us get this kind of going in terms of he provided support.

We plugged that into just kind of a remotely-sensed GIS framework to get the probability of attraction — or the viability of a given lake for zebra mussel reproduction. So how much did the zebra mussels really dig this lake?

But, the problem with the report was that it was 12 different parameters, and there are aspects of it that can really be simplified because, again, if you want a proactive approach, you need the ability to have something that you can generate relatively quickly.

We were able to get five different parameters. That's what is highlighted in bold-faced fonts. And then we just ran a suitability-based model on top of those parameters to generate habitat suitability.

Next slide.

So – and then the final model we had was a population dynamics model that basically simulated the different life stages of zebra mussels: so juveniles, larva, juveniles and adults at each given lake. And we used the literature and evidence from experts on, basically, what survival over each life stage was.

And, basically, the idea is that when this is incorporated into the boater-behavior model, you get an idea of are the zebra mussels going to survive in a lake? If they run into a boat, what's the probability that they're going to grab onto that boat? What's the probability that that boat will go to another lake? What's the probability that the zebra mussels will survive going to that lake?

So – next slide please.

On this slide, this is our integrated model. And it's actually – up at the top of the screen you see a network-driven yellow and red bunch of lines connecting a bunch of other lines. What this is the gravity model actually calculating the attractiveness of all the other lakes to one lake – one specific lake. So if you're sitting in a lake, what this model does is it tries to figure out where you would like to go, based on all the lakes within the Watershed.

And so the idea — and this was all programmed into NetLogo, which is an agent-based modeling framework, and it's a really cool program — but it will actually run simulate this over time and figure out where the lakes are. And unfortunately, the video it's going to show you won't work, since it's on my computer, but the idea is that this simulates boater movement over a season, and we generate patterns.

These patterns can then be compared to where zebra mussels are. And, what we can do is we can actually kind of start to validate this model based on the size – based on our parameterizations of the gravity model.

The cool thing about this is that this gravity model can actually be – you can incorporate different things depending on where you are and how much you know about the system.

What our model showed was that it identified three areas that were highly likely to contain zebra mussels. And so – and then when we went back and looked at it, and I don't remember the names of the lakes at this point, but the zebra mussels were already there, so you know, well, that seems likely.

But what it really showed us was that the proactive approach is really going to be needed. We've got to figure out some way to stop the dispersal, because if you don't and people are still boating all over the place, and even if you have one or two people that don't clean their boats, you're still – the zebra mussels still have a pretty high probability of spreading over a long period of time.

Next slide, please.

What our results showed us was that the zebra mussels are – they're going to be difficult to contain at northern latitudes. They love it in the North. We have a project going on with Texas State University right outside of Austin that's looking at zebra mussel dispersal in the South, which is the southernmost latitude that this species has ever been found, and it's still surviving down there.

One of the experts out at the University of Texas at Arlington, his hypothesis is that temperature will drive the dispersal because they've never been exposed to high temperatures that Texas experiences. So hopefully, you know, we're collecting data through the summer, and so, hopefully, everything will kind of work out so we can see if that's actually the case.

You know, the limiting factors aren't that limiting. That was another thing we discovered. So the habitat suitability really does need some refinement. And the cool thing is the gravity model can be parameterized with whatever

information you have and, you know, it needs some further refinement, but it's totally usable now.

In addition, you could put stuff in different types of fisheries. Like, if you know that people go to catch a certain type of fish and that's an active recreational fishery, that can be incorporated into this approach, and then you can rerun the model.

I said this earlier, but turbulence results haven't been incorporated but, hopefully, when we get them incorporated, that should provide some more management, more tractable management strategies.

Next slide.

So, I would like to thank everybody that was involved with this project. I – you know, (Dan Kelner) out at St. Paul District has been helpful. The National Park Service, St. Croix River Watershed Research Station, St. Anthony Falls Lab, (Mike Kjelland) – Dr. (Mike Kjelland) and Dr. (Candice Piercy) on my team were – you know, they put a lot of this stuff together. And, this was funded through the Aquatic Nuisance Species Research Program.

In addition, we just received some funding to continue the gravity-driven approach with the U.S. Bureau of Reclamation. And so, you know, we're really excited about being able to continue some of this work.

Next slide.

And this is my team. That's Dr. Piercy on the left. Dr. Kjelland in the middle, and me freezing in Minnesota in July with Dan, who's in the right picture.

And so, yes, we went out there to do some sampling, and it started raining, and it dropped into the 50s, and I had flown in from Texas and was not quite prepared for that.

So anyway, I will be happy to take any questions. And, you know, please, if you can't think of anything now, and you think of something later, please feel free to email me. And because I think this is an important issue, and I think that everybody – we can all work together to solve this problem. Thank you very much.

Julie Marcy: Great, Todd. Give me just a minute and let me unmute the line.

Operator: All participants are now in Interactive Talk Mode.

Julie Marcy: Okay. Your lines should be open now. Remember, if you used the individual mute button on your phone, you will need to disconnect that as well. We'll go ahead and open it to questions, either in Chat or on the phone.

I have one Chat question already for you, Todd.

Dr. Todd Swannack: Okay.

Julie Marcy: How can we identify high risk lakes that don't have zebra mussels?

Dr. Todd Swannack: Oh. That's a fantastic question. So in some — so it's unfortunately not a simple answer, but one of the – surveys are a great way to do it. I mean that is the only real way, is to get out there and actually look.

The issue that we have run into is, you know, there are areas that have been heavily surveyed, particularly up in the North where this has been problem much longer.

As you move West or South, the – we're having to rely on other types of technologies because we don't know if they're — they can be hard to detect before they hit that critical mass where they just take over, and so techniques like environmental DNA – or eDNA – which samples water for the DNA of zebra mussels, and then you run DNA tests on that water.

Those have been really promising in at least identifying the potential for them to invade. Sometimes you'll get a positive eDNA reading, and but you can't find them. But their DNA is in the water somehow. So it's – that is I think – that's kind of where we are at this point. Did that answer the question?

Woman 1: Well, I was the one that asked the question about how we can identify at risk lakes. So based on that model, I guess what I was asking is, can you say, what's the probability that these lakes are more at risk of getting (zebed) than these other lakes?

Dr. Todd Swannack: Yes. Okay. I'm sorry, I misunderstood. Yes. So based on the habitat suitability approach, we can identify areas that are more likely to have viable populations if they're introduced. So…

Woman 1: Right. I guess what I'm trying to say is can we say, oh, these lakes are the most at-risk; therefore, we should be putting increased efforts to prevent, maybe boat inspections at those specific lakes.

Dr. Todd Swannack: Yes. You can do that. You can actually run, like, a habitat suitability model. So you can actually decouple the habitat suitability stuff to figure out

the lakes that have the highest likelihood for survival. And then, you could run something like the boater-behavior model on top of that to figure out which has the highest likelihood of being visited by boaters, and then you can couple those two together to get a result of highest risk.

Woman 1: Good. That certainly is the answer. Thanks.

(Tim Lewis): (Tim Lewis) here.

(Tim Lewis): Question for you. Quagga mussels seems to be more of a problem at southern latitudes and west of the Mississippi. Will this modeling approach be applicable to quagga mussels too?

Dr. Todd Swannack: Great. Fantastic question, and thank you. Yes. It will. The work we've got with U.S. Bureau of Rec is actually to not only incorporate the gravity-based approach for zebra mussels but also for quagga mussels. They have really similar live history strategies, and so we're currently working on figuring out how to make it more applicable to quaggas as well. So yes, we have a work unit right now specifically to look at that.

(Tim Lewis): That's great. Thank you.

Julie Marcy: Any additional questions? Go ahead.

(Jeff Trulick): Todd, (Jeff Trulick) at Headquarters. How are you?

Dr. Todd Swannack: Hey, (Jeff), how's it going?

(Jeff Trulick): I'm good, thanks. Are you aware of the effort — I believe it is in the Seattle District, I can't recall exactly. That is under the latest (WRRDA) section 10-

39 they have an effort going on to locate washing stations. With State partners out there for hydro gunning or inspecting for boats for mainly quagga and zebra, but they can do any type of invasives like Hydrilla, grass, or something like that.

They are ramping up to do a letter report on this. It is about a $250,000 effort, I think. The results of it would be cost-sharing these inspection stations and mainly funding them with the states out there. They have several states involved.

I think it is the Columbia River basin. I can get you more information on that, but I just wanted to make sure you knew that because I could see your risk model may be helping them a bit as they roll out on the annual scrub of where to put these mobile hot stations, or mobile wash stations.

Dr. Todd Swannack: Yes. I did not know about that, but if you don't mind emailing me some of the information, I can get in contact with them, because that — something like this model would be ideal for identifying, like, potential areas. That could even further the first question about how to predict where they would be. You know this could actually help with that proactive management.

(Jeff Trulick): Yes. I'll flip you the information.

Dr. Todd Swannack: Cool. Thanks.

Julie Marcy: Any additional questions for Todd?

(Deanie): This is (Deanie): I just have a comment. Todd, I think that was a wonderful presentation. It was very clear at how you put all the pieces of these models together. I see lots of applications, and I thank you for sharing all that.

Dr. Todd Swannack: Thank you, (Deanie), I appreciate that. Thank you.

(Deanie): You're welcome.

Julie Marcy: Any additional comments or questions?

Dr. Todd Swannack: And again, please feel free to email me if you have – if you think of something later. You will definitely get a reply and, you know, I'd love to talk more about this stuff with everybody. So thank you.

Julie Marcy: Oh, and we just had another one come in on Chat, Todd.

Dr. Todd Swannack: Okay. Cool.

Julie Marcy: Does this habitat parameter model apply at all to river habitat suitability?

Dr. Todd Swannack: Oh, gosh. Good question, and the answer is no, not right now. We are working — the project that we've got going on in Texas, I have a grad student who is – that's part of her Master's thesis, just to kind of to incorporate some of this stuff into her — because she's only working in rivers — and to figure out how we can transfer some of the habitat suitability stuff to river systems.

Julie Marcy: Great. Any other questions on Chat or verbally?

All right. Well, again, if you do think of something, you can follow up with an email or call Todd Swannack. Todd, thank you so much for sharing the great results from your modeling work today. Certainly zebra and quagga mussels are on the minds of many people across the country that deal with waterways

and water bodies, and sounds like you all are making some really good progress there.

Thank you to all the attendees for participating today. As I mentioned, we should have the PDF of the PowerPoint posted fairly quickly. If you need it right away or something, just send me, Julie Marcy, an email, and I can get you an advance copy if you need that.

We'll also be posting the video, which is the slides with narration. Then, we'll need a little bit more time, but we should have the transcript of the audio portion as a follow-up posting as well.

Todd, thank you again. Participants, thank you, and I hope everyone has a great afternoon.

Dr. Todd Swannack: Yes, thank you very much. Everybody take care.

Julie Marcy: That will conclude our meeting. END