Webinar Transcript

Rangewide Climate Vulnerability Assessment for Threatened Bull Trout

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Ashley Fortune Isham: Good afternoon from the US Fish and Wildlife Services National Conservation Training Center in Shepherdstown, West Virginia. My name is Ashley Fortune Isham. I would like to welcome you to our webinar series held in partnership with the U.S. Geological Survey National Climate Change and Wildlife Science Center in Reston, Virginia.

The NCCWSC Climate Change Science and Management webinar series highlights their sponsored science projects related to climate change impacts and adaptation and aims to increase awareness and inform participants like you about potential and predicted climate change impacts on fish and wildlife.

Today's webinar will focus on range-wide climate vulnerability assessments for the threatened bull trout with Dr. Jason Dunham. Please join me in welcoming Emily Fort from the National Climate Change and Wildlife Science Center, who will be introducing today's speaker. Emily, welcome.

Emily Fort: Thanks, Ashley. Thanks to everyone for joining us. I'm here to introduce Jason Dunham. He's an aquatic ecologist with the USGS Forest and Rangeland Ecosystem Science Center in Corvallis, Oregon, and has been working on research related to bull trout for almost 20 years.

His work also spans a variety of other species and ecosystems, ranging from native salmon in Alaska, to non-native salmon invasions in Chile. Jason received his PhD in Ecology Evolution and Conservation Biology from the University of Nevada at Reno.

Prior to his current position, Jason served as a research fisheries biologist with the US Forest Service Rocky Mountain Research Station in Boise, Idaho. Jason, please, we're looking forward to hearing from you.

Dr. Jason Dunham: Hey, thanks Emily. Can you hear me OK?

Emily: Yup, loud and clear.

Jason: Terrific. Thanks everybody for dialing in today to hear about this great work. I really appreciate everyone's support for the project. I wanted to start with a thank you. Thanks to the Fish and Wildlife Service here in Oregon. Their Science Applications Office, Steven Zylstra provided some funding for this, as well as the Climate Science Center, and the Northwest Region of USGS.

I'm the lead on this project, but couldn't have gotten it done without help from my team. Dave Hockman Wert was our Spatial Analyst, our GIS person. Nate Chelgren, pictured there on the right hand, he's our resident Bayesian in the lab, quite handy.

Mike Heck, who deals with everything else that falls through the cracks. He's our leather man tool in the lab. Throughout the study we've had help from Dan Isaak as many of you know, he and Seth Wenger have been working on the NorWeST Temperature Prediction Project, which is a very key piece of this assessment as well. I just want to give all these guys a shout-out, and couldn't have got it done without them.

Here's an outline for what I'm going to go through today. I'm going to try to keep it somewhat short. No one ever complained when a seminar ended early. Hopefully there will be plenty of time for questions. I'm just going to go through a little bit of bull trout 101 to begin with in case folks are not already familiar with this species. Then I'll give you a brief description of what the rangewide vulnerability assessment is, and we'll describe some results that we have to date, and then let you know what we're going to be doing in the future.

Bull trout is one of three chars of the Pacific Rim. Chars are fishes of the genus *Salvelinus*. I know folks who are dialing in from out east. Some experts there studying brook trout, which is an important native species out there. Lake trout may be another familiar one. But here, around the Pacific Rim, we've got bull trout in North America, western North America, and Dolly Varden to the north. Dolly Varden wrap all the way around into Asia, getting into Northern Japan, where they overlap with the white spotted char.

This will give you a sense of what these critters look like. These are Dolly Varden on the left, from Japan, on the right, from Alaska. The fish on the right probably just got back from the ocean. On the lower left-hand side of your slide is a whitespotted char. This is a picture I took of a fish in Hokkaido.

Surprisingly, white-spotted char is the closest cousin to bull trout here, in North America. Dolly Varden is more closely related to Arctic char. Finally, there's a shot of a bull trout from here, in Oregon, in the Metolius River, taken by Jeremy Monroe.

These are the kinds of places these fish live, headwater streams, and, as you can tell, a broad diversity of headwater stream habitats. The upper left-hand panel is a shot of a bull trout stream immediately following the eruption of Mount Saint Helens in the early 1980s. You can also have bull trout...Pictured in the upper right-hand slide, this is a coastal stream with a very flashy flow regime that can persist in there, as well as in more traditional cold headwater streams or spring creeks, such as the one pictured on the lower right-hand slide.

They're everywhere in different types of streams, but one thing all chars have in common is they like it cold. They are the most cold water Salmonidae, salmon and trout, in the world. Once you get above maximum temperatures of about 15 degrees Celsius, these fish really start to suffer physiologically, and definitely the case for bull trout as you can see in this graph here.

This is relating probability of presence of bull trout to temperature. It really starts to drop once you get to about 15 degrees Celsius.

Water temperature is important in the part of this world. It's the number one source of water quality impairment under the 303D list. In the region, we've got over 30,000 miles of streams listed for temperature impairment across Oregon, Washington, and Idaho.

This map of Oregon shows you some of those streams outlined in the red color. Here's a graph showing you how important water temperature is relative to other water quality parameters in this part of the world. It is driving the bus here. It is important for bull trout, but it's also important for water quality in general.

A few stats on bull trout. We didn't even know that bull trout was a species until 1978. It was synonymous with Dolly Varden until it was formally described. Then, it was petitioned for ESA listing in 1992.

It was listed in different parts of its range as a threatened species in the US between 1998 and 1999. There is critical habitat designated for bull trout. This was done in 2010 by the service.

That includes almost 20,000 miles of streams, almost 800 miles of marine shoreline and almost 500,000 acres of lakes and reservoirs. It affects quite a bit of the landscape here in the Pacific Northwest.

I'll move on to talk about what the vulnerability assessment is, basically four steps. Step one is to map suitable habitat or what I call "patches" for bull trout across the species range here in the lower 48.

Step two is to attribute these patches and migratory habitats with information on local and climate-related threats. I'll talk about what those are in a few minutes.

With these pieces in hand, we can model persistence of bull trout in these patches and give you a sense of where they're likely to be present, where they're not likely to be present across that vast range that I just described to you here in the Pacific Northwest.

Finally, I'll talk about how we're starting to apply these results to conservation efforts here.

Step one, map suitable habitat patches. When I say patch, patch could mean anything in a landscape, anything that's more homogenous internally relative to other pieces of the landscape.

Here, I'm talking about cold water, because we know that chars like it cold. Typically, you're going to find this cold water in the highest elevation portions of stream networks.

These are the places that are cold enough to support spawning and rearing for bull trout on a year-round basis. You can see that in this slide here, this cartoon of a network, that black outlined piece of the landscape is that cold enough, year-round piece or patch for bull trout.

Bull trout do range widely outside of patches. They get into places that may be unsuitable thermally on a seasonal basis, but they do make use of them when they're cold enough. That's something that we tried to roll into the assessment as well.

Why patches? This table, a little bit complicated for a presentation, but this gives you a sense of how patches fit into... the scale that we're talking about. We're not talking about sites or little places in the streams. We're talking about headwater networks.

Those patches in turn can be comprised of patch networks, so relationships among patches. You can scale those up further to sub-basins or to regions.

In the middle column of this table, I have a brief description of how this relates to the scaling that is used in the bull trout recovery plan. On the right-hand side, some potential indicators. In our case, we're looking at patch size, how patches are connected, how conditions are playing out within a patch.

The patch scale is a bit different from what we've done in the past on bull trout. You can see on the left-hand side of the slide is a figure taken from a paper by Seth Wenger et al, published in 2011. In this case, we looked at presence of bull trout in sites.

You can see those little dots distributed across the landscape that we studied in this particular publication. A lot of those little points or dots or sites are nested within a single patch. We know that they're not independent. We know that we need to deal with that. That's why I'm taking a patch-based approach.

If you look on the right-hand side, this is the HUC-based view of landscape. This is what the service used in 2008 for their core area assessment. These are fourth code HUCs. Nested within each of these HUCs are dozens of patches.

This scale's a little bit too big, I would argue. Sites are a little bit too small. I think patches are basically just right in terms of being defined based on the species requirements and scaled or tailored, if you will, to the species.

We're creating patches from a spatial temperature layer that is created by the NorWeST project. This is led by Dan Isaak. Essentially they have cobbled together thousands of observations of stream temperatures across the domain that you see on the left-hand side of the slide.

They've been able to model and map maximum and mean temperatures for the month of August at one kilometer intervals throughout the stream networks across the entire extent. It's a really huge effort, extremely valuable for us.

With those temperature predictions in hand, we can classify portions of the landscape that are suitable or not suitable for bull trout and see how those are patchily distributed.

On the right-hand side of this slide, I've got the details of how we delineated patches. You can ask me about that later if you want, later in the presentation. On the left-hand side, what you see here are red stream lines. Those are places that are too hot for bull trout.

The dark blue lines are places that are cold enough. Those are patches, networks that are cold enough for bull trout and known to be currently occupied. The light blue are places where it could be cold enough to support bull trout, but we've not observed them to occur there. Three different types of streams in our world.

The second step in this process, once we have those little pieces, those puzzle pieces, those patches, is to attribute them with different characteristics. The first thing that I thought about was to consider connectivity.

That is, connectivity between or among patches within these networks, so looking at distances between patches as well as their connectivity to migratory destinations used for feeding, refuge or overwintering. Two types of connectivity, connectivity among patches and connectivity to lakes and reservoirs. Those are incorporated into the model.

We looked at human influences in terms of non-native trout presence. We had good information on the presence of non-native lake trout. Lake trout is a char. It's not a native species through much of the bull trout's range, although they do coexist naturally in the Saskatchewan basin on the east side of the Rockies.

Surprisingly, we didn't have good enough information on the presence of non-native brown trout or non-native brook trout pictured here in the slide. These two species are listed as threats to bull trout, but one thing we learned through this assessment is we don't know enough about these non-native species to include them in the model yet.

For human influences, sort of a generic indicator of human influences, we used the human footprint. You can see a clip there from the publication. This was published in "Ecological Applications" a few years ago. This is a generic indicator of human influences across the landscape. It incorporates a lot of different factors.

In terms of climate influences in these patches, this is something of particular interest for us, we looked at patch size. That was our first variable of interest. It's how big is that chunk of cold water in the landscape. Does that have something to do with the presence of bull trout?

Within that patch, we also asked how much really cold water you have. For us, really cold water is a water temperature of 10 degrees or less for an August mean temperature. That's very cold water. That could be important for egg incubation of bull trout or perhaps maybe a refuge from disease or some other factor.

The second thing we focused on was winter floods. We know that winter flooding is going to increase as snow goes away in the West. It turns into precipitation in the winter. We know that this sort of high-flow event could scour bull trout redds or nests or displace juveniles.

We looked at the percent of patch length with w95, that is a winter high-flood event, less than two of those. If it had a low flood frequency, we predicted bull trout to be more likely to be present.

We also had information on wildfire, the monitoring trends, in burn severity datasets. There's a really good one for this, the MTBS. We looked at the percent of a patch in terms of its area with a severe wildfire in the last 20 years. That's another very climate-responsive variable as most of you probably know.

Here's a horrendogram showing you how things are related to each other in my mental model of how these variables all conspire to influence the presence of bull trout in patches across the landscape.

The yellow circles are the variables that we have information for in this analysis. Essentially what we did after attributing the patches, after delineating and attributing them, was to conduct a big logistic regression to look at how the presence of bull trout, zeros and ones, presence or absence, is related to all of these variables.

In a nutshell, these are the variables that turned out to be more important, only four of them. Flow regime, as we hypothesized. Thermal regime, which we expected as well. Stream length in a patch, that's our measure of patch size. It turned out to be a major driver, as well as the human footprint.

Surprisingly, things like patch connectivity or migratory connectivity didn't turn out to be important. Neither did presence of non-native fish. Remember, that was only lake trout that we were able to look at.

Let's talk about these variables that turned out to be significant in the analysis. I have some slides at the end of the presentation if you have questions about things that turned out to be not significant. I'm ready to discuss those if you want.

In terms of temperature, we found that it was doubly important. Not only do bull trout need large cold patches of stream networks in the landscape that's less than 13 degrees Celsius, they also need very cold water within those patches. There's two pieces, cold enough and very cold.

Like I said before, that very cold water might have something to do with spawning and rearing requirements, egg incubation for the species. Most chars need really cold temperatures for egg incubation. Essentially this is a form of what I would call thermal habitat complementation.

You need different thermal characteristics for different parts of the life cycle. Patch size we know is important, because it's likely to lead to larger population size or just a larger area that is less vulnerable to a single large disturbance, like a debris flow or other effects from big disturbances like wildfires or floods.

In terms of climate, the question here, of course, is how much will this cold water warm. The answer to this is all over the board. Generally, from what we know right now, is that interestingly, cold waters are actually warming less than warm waters or warm streams. That's good news.

The bad news is that cold water is going to go away with climate change. We're just not sure how much.

In terms of the W95 variable, this is the winter flooding variable. It turned out to be a really good predictor of the presence of bull trout. Like I said before, this sort of flood we think is more likely related to displacement of juveniles in the winter.

Bull trouts spawn in the fall. Their juveniles emerge sometime in the winter. They're very small, less than 30 millimeters in size, not real good swimmers.

Winter flood is not a very welcome event. Like I said before, we know that winter floods are going to become more important as we lose snow and ice across the range of the species.

The human footprint also turned out to be an excellent predictor of the absence of bull trout. The bigger human footprint index, the less likely to see bull trout in a patch.

This was the best we could do. It's a catch-all indictor of human influences. It doesn't point to any specific factor that we might think of as being important for bull trout. It doesn't tell us anything about stocking of non-native trout, angling pressure.

It doesn't deal with small barriers, things like stream/road crossings, culverts, water diversions, levees, those sorts of things. Anything that wasn't in the Army Corps of Engineers dams database, we weren't able to incorporate into this analysis.

There are various other sorts of local factors that you could list that we don't have good wall-to-wall data on. That's one thing that really came home to us in trying to do this work. You really need data on these little things that can make a big difference for fish on the landscape. We don't have those spatial databases.

That's the story for patches. What about patch networks? How do the effects of these variables I just talked about, how do they vary among the different sorts of units that we split bull trout into?

What we did here was included a random effect. We allowed the coefficients for those different variables to vary across core areas or other units. Core areas turned out to be the most informative for us, these polygons here in this slide show you the currently designated core areas for bull trout across the species range in the lower 48.

We allowed the effects of temperature. We allowed the effects of stream flow and the effects of the human footprint to vary across all of these core areas. Here are the results.

The values of the coefficient are on the Y axis, the vertical axis of this graph. Then, you can see different recovery areas listed on the X axis. Within each of those recovery areas, each dot is a core area.

Recovery areas are larger extents within which you have core areas nested. Each dot is a core area. You can see in the upper left-hand graph, that's for patch size, that length of the network, length of cold water, you can see the coefficient is all over the board for that.

There is no such thing as a universal, magic patch size for bull trout. It really depends on the core area that you look at. That was a very important take-home from this analysis.

Until we get some of the other coefficients, they don't seem to vary as much. There is some variation that could be important. Interestingly, the very cold variable, that's the V_cold, is highly invariant among the core areas.

The red dots indicate core areas where we had a significant effect of that particular variable. The unfilled blue outlined dots are places where it was not statistically significant, so some interesting variation there as well.

Move on to the final step, applications of predictions from this model. What you're looking at here is the extent of the range that we've been able to cover to date. This was the point at which the NorWeST effort had completed modeling and mapping stream temperatures when we wrapped up this work last fall. We're continuing to finish the whole range now that we have all of the temperatures available.

We're going to zoom into these four different boxes, these portions of the range that represent some interesting variation across the range of bull trout in the US. Here's a zoom-in to those four locations.

What you're looking at here in terms of the stream lines are what we call "prediction anomalies." In red are patches where bull trout are thought to be present, but the model predicted them to be absent.

In yellow are places where bull trout are not known to occur, but the model predicts bull trout to be present.

Take a look at panel A. That's in the upper left-hand corner of this slide. This is the lower Pend Oreille basin. Lake Pend Oreille is that sort of snaky lake there on the lower right-hand side of that panel A.

If you get down into the lower Pend Oreille basin, you'll see three red streams. Those are patches where bull trout have been observed. People thought bull trout should be present, but the model thinks they should be absent. It turns out that people have looked for bull trout in these places for the last 5 or 10 years and haven't found them. The model could have told us that.

The orange or yellow network in the lower part of the Pend Oreille basin, that is unoccupied because there is a dam there that is not in the Army Corps of Engineers database. The model picked up on that. It's like, "Hey, how come bull trout aren't here?"

Currently, folks are talking about a bull trout reintroduction in that particular patch. The model would tell us that might not be a bad idea.

Looking across other portions of the range you can see a number of places where you have these small networks outlined in red, where bull trout have been observed. The model says they should be absent.

Those are generally the smaller patches across the landscape. There's a few exceptions here and there. A lot of these places where the model thought bull trout should be are upstream of barriers that we couldn't track in our database to fit the model.

Even though those aren't in the model itself, the model is showing us that those are big patches of cold water that could be suitable had those barriers not been there, just based on looking at these prediction anomalies.

Notably, in the lower panel, panel D, the model is predicting that bull trout should be present downstream of Anderson Ranch Dam. This is in central Idaho. Anderson Ranch Reservoir is a huge reservoir. It has a hypolimnetic discharge, very cold water coming out the bottom.

Based on the NorWeST predictions, it's a cold stream now. The model thinks bull trout should be there. In fact, bull trout have started moving into that reach of stream since it's cooled down. Nobody's documented them spawning there yet, but we haven't looked that hard.

It's worth noting that we have those predictions available for literally thousands of patches across the range of bull trout. There're a lot of places we've not looked for this fish. That alone is a huge help in terms of us strategizing, in terms of monitoring and evaluation of those species across its huge range.

We can't sample everywhere all the time, so having those a priori predictions is a huge help. They can help us focus our efforts and save money in the long run.

In terms of the next steps, we're going to work to finish the species range. This is a map of the thermal scape of the bull trout's range, a little bit bigger than the actual extent of bull trout, but the bull trout's range is nested within this. It's all done.

We're busy creating new patches, attributing those patches. We'll be fitting final models to cover the entire species range some time later this spring. The whole thing will be done in the lower 48.

The next step, following that, will be to project what might happen to bull trout patches in the future. We're going to take a look at a very optimistic climate and emissions scenario and a pessimistic climate and emissions scenario.

We're going to pull that out of the NorWeST database and see what that looks like for bull trout. We've done this before for the species, but the models that we've used before are based on associations between bull trout and air temperatures. I'm not sure of a good way to say this, but we've been projecting hot air to look at climate effects.

That's all we had before the NorWeST effort was available. When you project air temperatures, things don't look so good for bull trout.

My prediction is that in looking at water temperatures, we're going to get a considerably more optimistic story. Overall, bull trout are going to lose a lot of habitat in any sort of warming scenario, but it's not going to look as bad as it does for air temperature.

The other thing we're considering doing in these climate scenarios is given a climate scenario, how much can we change that human footprint to make a difference? How much can we do to minimize human influences in a very generic way, as indexed by the human footprint, to see if we can adapt, in the climate sense, to climate change.

Like I mentioned before, another important next step for us is to do what we can to try to learn about those little things that we weren't able to incorporate into this assessment. I mentioned presence of non-natives, at least brown trout or brook trout.

We don't know that. Small barriers, there are thousands of them. Diversions, the same thing. We need to get better information on these little things to really know what's going on.

To help with this, we've put together a number of what I call patch attribution tools. This is one that we put together using Google Earth. This allows managers to attribute these patches with their expert opinion or their actual real data on the presence of bull trout or these non-native fish, like brown trout and brook trout.

We're working right now with the state of Oregon. They are adopting these tools. They're working with their district managers to get us this data so we can come up with an improved assessment at least of the effects of those non-native trout on bull trout. Trying to move that forward.

As this comes to a close, we'd like to find ways to use these results in local vulnerability assessments, local conservation assessments. Here's one example that's just out in the "Canadian Journal of Fisheries and Aquatic Sciences." Here we looked at climate vulnerability of bull trout in the Wenatchee River basin in the context of managing wildfire.

I won't get into this in too much detail. Here you can see how we have drawn the patches in the Wenatchee River basin and looked at their vulnerability as a function of future wildfire regimes. All those little tiny polygons within the passes are giving us a picture of how habitat conditions are going to change based on wildfire.

What we learned in this particular paper, in a really small nutshell, is that if we manage for wildfire, that can be a very effective way of buffering bull trout from the effects of climate change under moderate scenarios for climate change.

If things change very strongly, and climates really warm substantially, there's not much we can do to protect the species, but definitely, managing fire, which is not a small task, is something that could be effective. Managing for connectivity, we found out in this particular analysis, is considerably less effective than managing for fire.

Very interesting to use results like this to contrast the effectiveness of different management strategies, both of which are very expensive. Good to know in advance before you do this.

Hopefully I'm wrapping up a little bit early here. I just wanted to point you to the website where all this information is. All our data is posted there, available for you to use as you like. We've got several publications, including a more detailed report based on the vulnerability assessment that you can access there.

Thanks for listening, and I would be very happy to take any questions, or have a discussion about this.

Ashley: David Hines, you can ask your question.

David Hines: Jason, you said all your data was available on that website. I just went there. Which link do I click on to find the bull trout data?

Jason: ScienceBase.

David: OK. Sciencebase.gov. OK. Thank you.

Jason: Yeah. Thanks, Dave. You can contact my Dave, too, if you want. You know where to find him.

David: Yep. I also sent you an email, too. Talk to you later.

Jason: OK. Cool.

Ashley: OK. From Lew Gorman we have a question. It says, "Since this species range has a large portion along the Canadian border, has Canada generated similar data?"

Jason: No. That's a good question. The first picture of a bull trout I showed, I took that up in British Columbia this year and gave a presentation on this up there, and invited them to join us. They're thinking about it. It would be awesome to have data from Canada.

It's much easier said than done, and there's definitely a north/south gradient in available data. Bull trout get all the way up into the Northwest Territories, and that might be a good spot to start studying them.

Ashley: From Don, "So, you have the assessment. What are the management implications?"

Jason: We can take a look at those threats and how those vary from place to place. That's very important in terms of thinking about the species' status. One of the reasons that threatened endangered species are listed is based purely on the threats. We can also take a look at that in the context of some of the local factors. I mentioned wildfire, managing connectivity, how does that play with climate change to influence our view of priorities for managing bull trout.

Another use is sampling. The predictions from the model give us an a-priori expectation of where bull trout should be across the landscape, even without dipping a toe in the water. That improves our ability to strategically target our sampling to find this fish. There are hundreds of places where bull trout could be that we've not looked.

Those are just a few examples of some of the management applications.

Ashley: And Don asks, "Less clearcutting?"

Jason: I'm a science guy.

Ashley: [laughs] We did have another question come in from Brittany. It says, "What is the US doing currently to protect remaining patches, and what do you suggest Canada can do better, or should do better?"

Jason: Well, I don't really have a big message for Canada. [laughs] Interacting with the Canadian biologists, they're excellent. I work with them a lot, and it would be nice if we could do a better job of coordinating on getting a common piece of information so it's not a rangewide vulnerability assessment for bull trout in the US, it's a rangewide vulnerability assessment across the whole species' range.

To me, that's really where I would like to go. We have so much uncertainty, so many questions, so many concerns about what climate is going to do to the species in the lower 48. Canada is definitely going to be a stronghold, and we know the least about it the further you get north. That would be the most important thing to do, I think.

Ashley: Thank you. We have a question from Sondra Collins. While you're typing in, I'm going to call on...I saw another hand up here. Chad, you can ask your question now.

Chad: Can you hear me?

Ashley: Yes.

Chad: Hi, Jason.

Jason: Hey, what's up?

Chad: Not much. A couple of the predictor variables were surprising, too, that they didn't come out as important. Do you think with maybe a little better data or more information that some of those would start to pop up as being more important?

Jason: Yeah, certainly so. Probably the biggest surprise to me, Chad, was the lake trout not having an effect on presence of bull trout. There's a few reasons for that. One is that we're looking at presence over the last 20 years, so maybe that invasion has happened so recently that we're not picking up those recent extinctions, or that lake trout are really depressing abundance of bull trout, but not causing them to go completely extinct, at least yet. We definitely have cases of that in Oregon, where they're able to coexist at the expense of bull trout

The other thing to keep in mind is that bull trout and lake trout coexist naturally in the Saskatchewan Basin. They've been there for millennia. I think it would be good to try to figure out how those two get along.

With other variables, like the fire variable, I don't know if that goes far enough back in time to really pick up some of the major events that have happened in some of those basins that could explain variability in presence of bull trout. It may not be a long enough time-series for fire, either.

A couple of examples of why things didn't come up that seem a little bit surprising. The connectivity variable, I think definitely better data on lakes and reservoirs. I was really amazed at how little we know about our standing water bodies in trying to get the data we needed. We don't know how deep they are, we don't know anything about their water quality. Some we do, but across the board, we don't. We don't have a national lakes database that's good enough to be incorporated in an assessment.

Just a couple of examples of things that I thought should have been important, but weren't.

Chad: OK. Thanks.

Jason: Sure.

Ashley: Seth Willey asks, "You predicted declines due to warming, but not as extreme as in air. In light of this, I'm wondering if you could weigh in on long-term prospects for recovery, potential viability to be returned, or not?"

Jason: Super good question. Remember, at the beginning of the talk I mentioned we have 30,000 miles of streams that are already listed as impaired for warm temperatures under the Clean Water Act. We've already done a lot to water temperatures to warm them up. You talk about climate effects on stream temperatures, you may be getting into two to four degrees warming. There are many examples where we have over 10 degrees of warming due to channel alteration, loss of riparian vegetation that provides shade to the stream, loss of water in the channel. A lot of streams are dry.

I think there's a lot that we can do to get these systems back in shape, just based on the legacy impacts alone. I do think that the vulnerability assessment provides this broader context and gives you a better picture of where those sorts of local restoration efforts are more likely to be effective in the centuries-long time scale.

There may be some places that, no matter what you do, you're just going to run out of cold water, but there are definitely other places on the landscape that you can see, in this assessment, where you can make a lot of ground up by those local management effects.

Ashley: Sondra was able to go through the chat, and ask, "What will be the team sampling schedule? When? Where? And is there a timeline available for the next five water years?"

Jason: No, we don't have any money to do sampling. If we get some money for dry suits and gas in the gas tank, or filters for environmental DNA, we'll be out there and do it, but right now there aren't any plans on my part.

Ashley: Then, Don also asks, "Is the research being utilized by management?"

Jason: Absolutely. As soon as we get it out, it gets used. Folks have been using it in Montana. That's where we started, Region One of the Forest Service Area. Scott Spaulding has used it in some of their bull trout conservation planning efforts. Other folks have been grabbing the patches and using them in other core areas. As soon as it comes out, it gets used.

Ashley: All right. That's all I'm seeing. Again, Jason, thank you very much. It was very interesting.

Jason: Yeah, great discussion. Thank you so much.

Ashley: Great. Our next NCCWSC's webinar is going to be on Thursday, April 16th at 5:00 PM Eastern. Yes, that will be recorded and posted to the NCCWSC's webinar page if you can't make it. We hope to see you then.

Please stay tuned for another announcement, or watch for an announcement over your email. Thank you again, Jason. Have a great day.

Jason: You bet.

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