The Potential Influence of Changing Climate on the Persistence of Rocky Mountain Native Salmonids

Transcript, November 13, 2012 Webinar

Emily Fort: First of all, I'd just like to welcome everybody and good afternoon. We're happy to have you in today's broadcast of the National Climate Change and Wildlife Science Center Science and Management Webinar Series. It's a partnership with the National Climate Change and Wildlife Science Center and the US Fish and Wildlife Service National Conservation Training Center.

I'm Emily Fort, the Data and Information Coordinator at the National Climate Change and Wildlife Science Center. And on the phone, we have Dave Lemarie from the National Conservation Training Center, who will be facilitating the phone questions at the end of the conversation. So today's broadcast will be presented by Jeffrey Kershner and Steven Hostetler and will be focused on the potential influence of a changing climate on rocky mountain native salmonids.

I'll introduce our speakers in just a few minutes, but first, I just wanted to give you a few logistical details. First, to those of us joining us by phone, all of the phones are currently on a global mute and will continue to be so throughout the duration of the presentation. After the completion of the presentation, we'll open the conference up for questions, and we'll have instructions on how to unmute yourself.

So first, now, I'd like to introduce our speakers. Jeffrey Kershner is currently the Director of the USGS Northern Rocky Mountain Science Center in Bozeman, Montana. He's also an Associate Professor at Montana State University. For most of his career, Jeff has worked on issues related to effects of land management practices on aquatic and riparian resources. He currently oversees a research group of biologists and ecologists that address natural resource issues, including global climate change, fire ecology, fish and wildlife ecology, and the conservation of endangered species.

Stephen Hostetler is a Research Hydrologist at the USGS National Research Program in Corvallis, Oregon. He's also an Adjunct Professor in the Department of Geosciences in the College of Oceanic and Atmospheric Sciences at Oregon State University. His current work involves modeling past, present, and future climate and quantify interactions and feedback of climate systems in terrestrial and aquatic ecosystems. So with that, I'm going to turn it over to our two esteemed speakers, and I know we're all looking forward to hearing from them. So Jeff and Steve, please take it away.

Steve: I don't think I've ever been called esteemed in my life. I've been called a lot of things [laughs] but not esteemed.

Jeff: So the introduction of this project was...let's see if we can get things to move, here.

Emily: So we're having a minor technical issue with the presentation not advancing. Give us just one sec. All right.

Jeff: What did you do?

Holly: I think I just clicked on the screen. I think it just wasn't active.

Jeff: Got it.

Dave: OK, it's looking good at this end. I think everyone can see the second slide.

Jeff: Great. Well, it's my privilege today, and I know Steve's as well, that we get to present work that is really a collaborative partnership between a whole bunch of people that involve the USGS and different disciplines within USGS as well as the U.S. Forest Service and Trout Unlimited, Colorado State University, and the Fish and Wildlife Service.

These folks that are up here on the board were all key players in this project, and in fact, I'm going to present much of what is mainly their work. So I thank them for letting me at least get this done. We had some remarks about the underwater photos that are part of the slide presentation, and these are taken by Johnny Armstrong, who's a PhD student at the University of Washington and will complete his PhD, defends on the sixth of December. So we wish him luck.

So a lot of people ask us why we started with trout, and one of the things that this group is really passionate about is that we all care about trout. And it's not just us that care about trout, but the public in general cares about trout. If you go all over the world, trout are found everywhere except for Antarctica. We could argue a little bit about whether they're supposed to be everywhere, but we don't do that in this presentation.

Somebody asked Harrison Ford one time why he cared about trout, and he said well, they live in all the best places. And they're probably enough said about that, but it's really true. Trout are typically found in mountainous habitats, nice, clean water. But then the great thing about trout is that generally from the standpoint of climate change, they're thermally intolerant to rapid changes in stream temperature, so they're a good bellwether.

When things start to change from the standpoint of air temperature, water temperature changes. And they're generally viewed as early indicators of climate change, so it's something that if we can take a look at trout and look at their habitat, we have a pretty good indication that things may be changing quickly. Because they're typically associated in the west, anyway, with mountain ecosystems, and we'll talk a little bit more about that.

And the other thing is that the existing threats to trout that have to do with habitat degradation and water withdrawals, things that are currently threats that sort of are playing a role in the life histories of trout, are potentially exacerbated or accelerated by the addition of climate stressors.

So what are the concerns that we're dealing with? Trout express a variety of life history strategies that the terms up there, fluvial, adfluvial, and resident, refer to. Trout that are fluvial essentially go back and forth between large river systems and smaller tributary streams. Adfluvial fish are fish that typically connect with lake systems and live with river systems in part of their life history.

We're also concerned about issues of isolation, in other words, what's happened to trout worldwide, in particular native trout in the western U.S., is that they have been isolated in headwater drainages by water withdrawals, by the introduction of non-native species, and so there are real issues with trout from the standpoint of how they connect up with their habitats all over the west.

And of course, we talked a little bit about habitat loss from a number of factors including overgrazing, logging, mining. Lots of bad actors there. And then the issue of non-native species invading trout habitat is a key one, and we'll talk a little bit about how climate is sort of related to this issue of non-native species.

So one of the things, when we first started this project back in 2007, that we were interested in knowing is: what are the things that really influence trout from the standpoint of climate. We had an initial project that started in 2008 that was sort of a 30,000 foot view of how trout are affected by climate change. And these are some of the things that we looked at in this first project.

We looked at this idea of the trends to warmer winter/spring reduced snowpack and earlier snow melt is probably an issue. It really does affect sort of how much water is available during the year for trout. If we have less snowpack, and our base flows occur earlier in the season. Same thing with the altered runoff regimes up there.

Again, trout, like the cutthroat trout we study in this project, are typically the descending limb spawners. That means that they spawn as flows go down with snow melt runoff. And when that occurs earlier, then potentially they interact with other species, like rainbow trout, that are ascending limb spawners, and potentially there's more interaction there from the standpoint of invasive species and this interaction is not always positive.

So the other part to this is that many of you have seen throughout the west is this idea that we're seeing more and larger wildfires. That was really apparent if you were anywhere in the west this year. We had smoke starting in early June and it lasted all the way to September when we had our first snows. So we were under the gun with wildfires all season long.

And then the last thing is this idea that we're seeing warmer summer temperatures in this graph in the bottom right. You can look at records that were set in places like Wyoming and Colorado this year and all over the west, it was warmer than normal. And this has resulted in warmer water temperatures for us and a lot of things that have some pretty strong implications for trout and long term survival.

So this project that we did in 2008, essentially we looked at populations of trout west-wide, like I said, at the 30,000 foot level, used some of the criteria that were presented just in this previous slide, and said well, what is our risk west-wide for trout as far as climate goes? And this composite graph that you see up here is essentially looking at green being low risk for populations, this yellow color being moderate, high, and very high. And you'll see the picture isn't a very pretty one.

But again, this was a publication that came out as an Open-file report in 2010, and it has more of the details in there. In fact, a lot of the work that you'll see here is referenced by publications, and there are publications essentially that are out or coming out within the next two months for all of this work, so there's a lot of data, and there's a lot of analysis here.

So we used this to say all right, well, if we've got this kind of composite risk, how do we sort of focus north-south, starting at the Canadian border and going south and looking at sort of a finer scale analysis of what's really going on out there.

Attendee1: What's inside the blue lines? Is that forest, national forests, or?

Jeff: Those are actual the ranges of the individual trout subspecies. I'm sorry. I should have said that before. And we'll talk a little bit more about those in just a minute or two, and I'll describe those. At the same time -- it was actually going on just a little bit later -- some of our group were working in what was called the Western Trout Assessment, and this was led by Seth Wenger, who's a postdoc with Trout Unlimited and worked with a number of us on this project.

And what Seth did is say all right, if we looked at the current models, climate models, what could we predict from the standpoint of habitat for all these different species across the west? The unfortunate part about this analysis was that the best data that we have actually is on non-native species on the west and that's for brook trout, rainbow trout, and brown trout. We do have some data on cutthroat trout. What we actually saw was that given what we saw with the current models, if we started looking at 2040 and 2080, the picture is not very good for salmonids in general across the west.

Cutthroat trout predicted reduction in 2080 was 57 percent and for the other species significant reductions as well. One of the interesting things about the brook trout and cutthroat trout dynamic in these water sheds in the west is that brook trout are non-native. This issue of changing hydrographs actually favors cutthroat more than it does brook trout because brook trout are fall spawners.

When there's less water and we get rain on snow events the prediction is brook trout are not going to do as well because their eggs are going to be in the gravel and we have these winter floods. It's an interesting sideline from this manuscript. Again, this was out in proceedings of the National Academy in 2011.

I wanted to show you where we located our fine scale analysis and what we wanted to do was take a north/south radiant approach in the analysis itself. We wanted to look at systems to the far north, which included the Flathead River Basin that crosses the Canadian border and into Montana. Then we had the Yellowstone cutthroat trout in Yellowstone, Wyoming, and parts of Idaho.

What you see in the far left in Idaho there is the Boise River Basin. Going down from the Yellowstone into Colorado is the Colorado River cutthroat trout. Finally, that small dot there in Colorado and a little bit of New Mexico is the Rio Grande cutthroat trout. Those were our fine scale analysis species.

The tasks we had in this particular project were that we needed to compile and produce these climate data sets to help us understand what's going on with climate. We wanted to develop hydrologic, thermal, and geomorphic models to downscale the climate models to look at stream habitats, develop some models from a biological standpoint that helps us predict what's going to happen to the trout populations.

Set the potential effects of climate change on stream habitats and trout species and then look at some decision support tools to help us integrate some of these changes and give managers some options. I'll tell you how we accomplished some of that.

I'm going to let Steve talk a little bit about the climate modeling part of this.

Steve: Part of this, as Jeff just said, for part of this project the expectation was for us to do a series of climate simulations with a regional climate model, dynamical downscaling, however you want to name it, over the west. We did that and these are just the domains we used to do it. We had four domains in the west and one in the east. This is topography shown on the domains.

You can see they're very high resolution. They capture the relief pretty well. The things that are important to force climate in the west are pretty well resolved topographically.

We did a series of simulations with four different climate models. We used GCMs to force these. The simulations are historic so 1968 to 1999 and then several of them run from 2010 to 2099 so we have very long integrations over multiple decades for a lot of these simulations so that we can look at not only climate change but changes in variability, abrupt changes, things we'd like to mine the data set for.

Also, it gives us a very long time series to work with in terms of some of the other models that we've done. We start our data in three to six hour time steps and then averaged it up to daily and monthly averages for this project and in general on our website.

We have a website, http://regclim.coas.oregonstate.edu. In that website now we have the ability to visualize the data, the ability to download the data. We have teaching examples that allow people of different interest and different levels of expertise to step through how you actually use climate data, some of the pitfalls, the pluses and minuses, et cetera.

We have an Open-file report that came out, too, as the data release for all of this. We have a number of collaborations, three projects, under this funding. We work with the CIDA, Center for Integrated Data Analysis, in Wisconsin, a USGS facility that now is able to mine our data set for their applications and to serve it in general.

Work with the BLM, Rapid Ecosystem Assessments, and a number of agencies and universities. We just released a new website on the eighth which now has daily data along with monthly data. Lots to do with diagnostic plots. We've incorporated new data sets and we're up to something like 430,000 files.

This is just to give you an example of what we've done. The website over here on the left, this is an example of using HUCs. We have nested geographic areas. In this example, we're going from HUC2 down to HUC8 in resolution. For each one of those HUCs, you can now click on the website to get plots of the climatology for each one of those. We're able to compare how our model simulates the observations and how it compares to the driving GCM.

You can get time series, which is the same data but now we're looking in time series for temperature and precipitation, same comparison. Then there's a whole series of scatterplots that give a nice idea of how well the model is matching the observations. These are really meant to be guidance so people aren't flying without enough information when they access our data sets. People need to know how good or how bad the model performs in the area of interest.

We also have this for states and counties and ecoregions - we're working on adding the ecoregions. The users can actually get a pretty good impression of how well the model is working before downloading our data and using it.

This is just an example of the website where you can grab data by area, by variable, and by time and model. It downloads in a netCDF file that goes right into any kind of application that uses netCDF including ArcGIS, or any application. The data actually flows completely into these applications along with metadata and all the information that's needed to use it.

You can also get the data by FTP and then the CIDA website you can actually upload shapefiles using the Geo Data Portal. You can upload the shapefile like the cookie cutter and extract data and download that data to your laptop or to your desk site to use the data for other applications.

From these data, I've put together this slide to get at some of the things that we're interested in in terms of the controls of salmonid life cycles. Across here, we're looking at different decades, so from 2029 to 2099 on the far right. This is for the A2 scenario. This is March snow-water equivalent, May soil moisture, and July temperature max.

These are the changes relative to today. The cross-hatching is where these changes are statistically significant. We make a big effort to keep statistical significance in the effort.

What you can see is the transition here for lots of snowpack through these time periods until we get out to 2090's and there's quite a large loss and significant loss everywhere. May soil moisture continues to decrease through the time and July temperature, over the time, is also increasing. These are the things that Jeff talked about earlier. These are the stressors, climatic stressors, that are going to come into play over the next decade.

In terms of disturbance, we're looking at wildfire. This is a composite of air temperature differences for high fire years in the west and low fire years in the west. High fire years occur when temperatures are one to two degrees above what's normal. This is looking at these same time periods, 2029, '40, '60, and '80 through time for the bottom third of wildfires, the middle third, and the top third.

The message here is that the middle third is soon going to become more prevalent than the extreme or the high fire years that we observe now so the transition to the climatology that will support wildfire and disturbances that will have a very big impact on streams and trout habitat is coming.

Jeff: We're going to transition into some results from a couple of papers. I'll be going back and forth between a paper that is coming out in December in “Fisheries” that is a retrospective analysis of all these subspecies. The data for part of this paper comes from that and then there's a modeling paper that actually tries to associate what's going to happen in the future for some of these species.

We have data from some of those, not others, at this point, but I'll go back and forth and talk a little bit about these. I'd be remiss if I didn't say what my colleague Clint Muhlfeld says every time he sees this slide which is the transboundary Flathead is arguably the most intact ecosystem in the lower 48. Clint opens every talk with that so I had to say it. I could not resist.

But he's right. It's an amazingly beautiful system, crosses the Canadian border. It's home of grizzly bears and westlow cutthroat and bull trout in large numbers. As you can see there on the right, some fairly impressive sizes for bull trout exist there.

In the transboundary Flathead, we have a number of issues that we'll talk about here that are consistent throughout this presentation as we go north to south, but what you're going to see from north to south is a gradual shrinking of habitat and constriction of habitat from north to south. Some of the threats that are more significant here may not be as important as, say, Colorado or New Mexico, but there are other things there that operate that probably have much more of an influence on those populations.

Of course, we've got glacier loss in Glacier National Park. Many of you have heard of this story before. Midwinter floods. Again, this idea that we're getting snowpack and rain on snow events more frequently in this trans-boundary flathead area is cause for concern from the standpoint of that we have bull trout that also spawn during the fall so their eggs are in the gravel during this time, so a significant concern for us.

The other issue up here is non-native trout invasions. I'll talk a little bit about the stocking that occurred of rainbow trout in the Flathead River system. Of course, wildfires are a large issue in this part of the world and we're starting to see more summer flow reductions and temperature increases, as well, and some of the things that Steve said.

I'm going to use a couple of terms in here and I wanted to define them before I did. We're going to be talking about spawning and rearing habitat. Those are in the blue lines that are up there on the map represented by the Flathead. Then the other term we're going to talk about is foraging, migrating, and overwintering habitat.

One of the things that Clint and a group of us did is that we actually applied some of Steve's downscale climate models to temperature data that we had within the Flathead River Basin, both air temperature and stream temperature sensors.

As a result of that, when we looked at the 2059 simulation of a model that Steve put together what we saw was about a 58 percent loss of this migratory and overwintering habitat that is throughout the transboundary Flathead and then about a 36 percent loss of the spawning and rearing habitat that's up there. You can see where the temperature thresholds are exceeded by the red lines in the diagram.

If we look at the 2099 simulation, our temperatures go up significantly. Again, we lose a lot more habitat within the transboundary Flathead for bull trout, which are typically a very cold tolerant species but don't tolerate warm temperatures very well. Bull trout are probably the bellwether of the salmonids most sensitive to temperature change in the group of fish that we studied.

This was an interesting analysis that appears in this retrospective paper that I was talking about that's coming out next month. One of the things that Clint had data on was Westlow cutthroat and hybridization that came from 1978. Along with the Montana Fish Wildlife and Parks, Clint has been able to essentially keep a monitoring program in place over this time period that goes up to 2007. In fact, it goes until current time.

One of the things that we've seen is that as temperatures have increased, particularly in the lower Flathead River system, we're seeing more of these rainbow trout starting to invade upriver into the warmer temperature areas. What Clint's seeing in this particular case is that hybridization is coming from these islands of rainbow trout, these propagules that live in the lower river, and they're spreading upstream and essentially they're mating with the native cutthroat trout and creating these hybrids that are invading further and further upstream.

The warmer the temperatures are it appears like the rainbow do better. We saw a very similar pattern in work that a graduate student and I did when I was at Utah State looking at trout across the border in the Kootenai River system. There were these propagules that did very well, with rainbow trout, and they were able to spread further and further upstream.

Again, this comes from some of Dan Isaak's work in the Boise River Basin. The Boise is an interesting place because it has native rainbow trout and it also has bull trout. What Dan did was to construct a set of diagrams from 1970 on for air temperature and the other was from 1945 and summer discharge.

What you see in these diagrams is air temperature in August is going up and has been since the 1970's and we're seeing a decline in summer discharge. The other thing that's happening in the Boise and throughout the west is that we're seeing large wildfires and some of those are sizes that we haven't seen for probably 100 or more years, particularly the wildfires in '92 that were extremely large and have impacted a lot of the watershed.

The interesting thing about all these changes taken together is that rainbow trout, which live in the lower portions of these watersheds, have now started to move upstream. When you look at the difference in habitat for rainbow trout versus where they were say 30 years ago and where they are now, there's really no net gain or loss because the rainbow trout, essentially, wouldn't occupy the cold headwaters but now those headwaters are warming and so they're moving upstream into those headwater areas. They're occupying habitat that used to be bull trout stronghold habitat.

Of course, what's happening with bull trout in this particular case is that bull trout are actually shrinking and occupying the headwater drainages but not as prevalent in those lower ends of these drainages.

From a modeling standpoint, looking at bull trout across the Salmon River Basin, for example, you can look at the 2000 to 2011 numbers and then look to the right and see an increase of two degrees C, which is projected by 2099, creates a whole bunch of unsuitable habitat for bull trout. We're going to see a pretty dramatic shift in suitable bull trout habitat over the next 100 years.

Steve: Another species that we've looked at a little further to the south is the Yellowstone cutthroat. This is a project that several of us have been working on, both Jay Alderon and myself and Robert Al-Chokhachy and some other colleagues at NOROCK. This is the Yellowstone cutthroat trout in the Yellowstone region.

You can see the typical habitat there on the right. These are high elevation. A lot of these streams are quite small. It's a pretty extensive range that's covered by the Yellowstone. The issues with the Yellowstone are pretty similar to the Western cutthroat with the exception of in much of it's habitat we have to deal with water withdrawal and irrigation. This is, actually, a very big issue in terms of providing enough flow and enough cold flow for the fish to begin with.

That's something that we're already dealing with. It's a stress on the system that's in place and anything else that happens in terms of disturbance or climate change is on top of that. There are two major river systems here, the Snake and the Yellowstone, that we're looking at.

We put together a distributed regression model that uses something like half a million daily air temperature and 150,000 stream temperatures and put together a distributed model over the habitat range of the Yellowstone cutthroat. One of the things we did with this is reconstruct the 20th century May thru September stream temperature anomalies. This is relative to the 1980 to 1989 time period.

You can see that through the early part of the century, temperatures were quite a bit cooler. We had an uptick during the drought period during the '30s. Somewhat more warming as we go on, but then in the '90s and 2000's there was a big jump. This is all from observed data so this is not modeled. This is actually what we're seeing in terms of temperature changes and stream temperature changes over the range of the cutthroat already.

We took the climate model and used output from the climate model to make stream temperature anomalies for the future. This is 2050 to 2059. Three different climate models, but you can see that the anomalies are somewhere between one and greater than three degrees, all of them warmer, and all of them up in the range of that one and a half to two degree where we start to see some real issues with the ability of the trout to adapt to it.

In terms of hydrology, we can see that the snow/water equivalent here in the upper Snake in the blue is the control period, the red is the modeled period or the future period. You see that there's an overall loss of snow/water equivalent monthly throughout the season and the runoff in the upper Snake changes. We actually have higher runoff early in the year, especially through May and June, and then a decrease and then not much change in the summer.

The Yellowstone shows a similar pattern. Pretty much reduced over all of the year, actually, and then changes also related to early snowpack melting and early runoff, which, again, as Jeff said, really has a big impact and influence on all the species that are spawning.

In terms of total growth potential, this map shows the changes in growth potential for the whole May thru September period. You can see that at high elevations we've gained growth and at lower elevations we've lost the growth potential, which has a lot to do with the temperature of the water. These are a few plots of the growth potential through the year.

For instance, in the Yellowstone if you look at the upper Yellowstone the cold water is actually now too cold for the fish, becomes warmer and actually much, much, much better for this fish so they actually gain quite a bit of growth at high elevation. At the low elevations, you can see that now there is a sag in the summer as warm temperatures inhibit growth. Under warmer climate conditions, there's much more of a sag.

What happens here is there's a tradeoff between the high elevations and the low elevations and, overall, the Yellowstone cutthroat actually look to be in pretty good shape because there is actually potential habitat for them higher up that's basically undisturbed.

There are competitions with the Yellowstone cutthroat and the rainbow trout. From the work we did, we see that in some places the Yellowstones outgrow the rainbows and in other places the rainbows outgrow them. Then there's also the issue of hybridization and connectivity as we worry about connecting the streams or keeping them connected at lower elevations and mid elevations. Will that actually allow the rainbow to invade further in and hybrid with the cutthroat?

Jeff: You'll notice as we talk about the next two subspecies, one of the issues as we keep going, and I mentioned it earlier, is that the current range for Colorado River cutthroat tends to be one of the overriding issues because they're limited in habitat already by things like fragmentation, water development, management, and the introduction of invasive species.

As we go further from north to south, you're going to see this issue of limited habitat become more and more of a question and more of a player as we go along. This work was done in cooperation with Colorado State University. James Roberts is the PhD student and now a Mendenhall. He's working with Kurt Fausch and a number of us on this particular part.

His prediction is that populations at lower latitudes and elevations in shorter stream fragments will be less likely to persist. We'll talk a little bit about that as we go along here. What James did is he worked with another one of our coauthors to work on using a Bayesian network approach to predict Colorado River cutthroat trout persistence.

Doug Peterson works for the Fish and Wildlife Service and Doug has actually done a lot of this kind of modeling in a past life. We'll talk a little bit about the publication that's come out of some of Doug's work in just a second. What they did is come up with some diagrams and their idea of how this process worked looking at the idea of stream fragment length influence, population size, the stochastic effects from things like wildfire, floods, that are going to influence habitat potential and population persistence.

Then, overlaid on top of that, is this idea of climate and changing climate changing maximum stream water temperatures and then the warmest 30-day temperature throughout the year. The time horizon of their modeling was 2040 and 2080 in this particular piece.

What we see is that currently if you look at the map on the right, that represents the range of Colorado River cutthroat trout. Wyoming, Utah, Colorado, down into New Mexico. Excuse me, not New Mexico. Wyoming and Utah and Colorado. This represents the bulk of the range here.

Right now what we see is those populations are typically limited to the high headwaters of the mountains in those three states. There isn’t a lot of connectivity to large river systems for Colorado cutthroat trout. When we look at probability of persistence currently, we have populations that are doing pretty well, but those populations don't have the ability to move downstream so they're forced to deal with habitat at much higher elevations and that habitat, typically, is much colder.

Currently, that habitat limits their ability to move and grow because it's too cold. As climate changes, it turns out that that habitat is going to be more available because it's going to be warmer so they have the opportunity to move upward and, of course, it's limited by how far they can move based on water and water availability.

By 2080 it looks like about 60 percent of the populations that are in this pool right now are going to be limited by the fragment size that's there and their ability to persist based on temperature. Even though they have the ability to move upwards, they really can't move anyplace else.

We're going to talk a little bit about a project that James is working on that actually looks at the influence of lakes and these high elevation lakes as potential refugia and places where we can mitigate some of the effects from climate change.

The bottom line for Colorado River cutthroat trout is the risk from warming is low because they're already restricted to these high, cold streams. Really, the issue for them is small fragment size. They just don't have the ability to occupy larger and larger fragments like we saw in the Boise Basin, like we saw in the Flathead or Yellowstone. They just aren't connected to these large river systems.

If you think about conservation, one of the issues that we talk to managers about is how can we increase fragment length and make more habitat for these species downstream? That involves a whole lot of management tradeoffs that include getting rid of non-native species, putting in barriers downstream as part of restoration, that are pretty intense and require a lot of effort and money.

One of the things that James wants to do as a consequence of this project is looking at: if you expand the length of the fragments of stream that are involved what's the risk of doing that? Are you better off keeping what you have from the standpoint of small populations and hoping you're not going to have a stochastic risk of extinction?

Or do you just say we're going to bite the bullet, we're going to extend the fragment lengths but we might have an issue with non-native species or other things?

The final subspecies we're going to talk about is a Rio Grande cutthroat trout. The Rio Grande is very limited from the standpoint of its habitat. We're talking very small populations of Rio Grande cutthroat trout. We're talking warming water by the modeling that's being done and disturbances that are more frequent, declining flows and water availability in that southern part of Colorado and northern New Mexico, and, again, this idea of small fragment sizes.

This is just to give you an example of some of the work that Andrew Todd and his coworkers have been doing. One of the things that they've been looking at is this idea of climate and wildfire. Of course, what you saw from the graph that Steve presented is that climate has an influence on wildfire frequency. This Medano Creek fire in Colorado was a big fire.

These fish are limited to small fragments within this water shed. The lower ends of the watershed are already too warm for Rio Grande cutthroat trout. If you look at the numbers from the Colorado Division of Parks and Wildlife in 2004 we were talking about 460 fish per mile. After the wildfire we're down to 191 fish per mile. Small fragment size, declining populations, real risk for extinction here.

At the same time, when you look at some of the data from the Colorado River and Rio Grande headwaters the last 10 years have been extremely dry down there. Not a lot of water. Again, we have issues with irrigation withdrawals, municipalities, a lot of competing uses for water. Pretty tough place to be a cutthroat trout.

Some of the take home messages from this are that climate change is going to compound some of the existing stressors that are out there. There's no doubt about that, as far as we're concerned. Again, the greatest risk is to some of these smaller, isolated, peripheral populations that don't have the ability to move or escape things like wildfires by moving into other drainages.

Managers really need to think about this restoration action and these high risk, high value habitats to increase resistance and resilience to climate change. Also, one of the things that we hear is that managers need to understand what all this is telling them, how they evaluate management actions in the face of climate uncertainty.

One of the things that Doug Peterson's been doing, and this manuscript, again, is coming out in the next issue, not this coming issue but the next issue, of "Fisheries," is looking at Bayesian belief networks and developing networks of variables that talk to the explicit nature of relationships between climate, temperature, life history, and how that's going to influence the persistence of cutthroat trout.

What's really interesting about this approach is that it allows managers to assign probabilities for each of these circles there and how they're going to influence the ultimate survival and the ultimate persistence of cutthroat.

In this example, you can look at the red up there represents habitat length of less than five kilometers and then as you go successive colors down to the green, which is greater than 40 kilometers, then you can look at those and say "with the modeling we've done what's the persistence probability for fish within this watershed?"

If you keep your eye on the green habitat as it goes along you can see that by the 2080's this place, these green habitats that are up here, are probably the places where we're going to have the last remaining strongholds of cutthroat trout. If you're a manager and you want to spend money and effort into trying to protect something you want to focus your effort in the places where you're going to have the best chance of success over the long term. That's what Doug's modeling has shown.

We actually have this with competing species, different species, invasive species. There's a whole host of things that Doug's done with this modeling.

Just a little bit about some of the work that we've done. We've got nine journal articles either accepted in press or published right now from this work. There are multiple articles that are in preparation or submitted. Steve and his students have three or four. I know from our shop we have another two and there are probably another three or four out there.

We've got three Open-file reports. We've held four symposia in conjunction with professional societies and we've got another one planned this spring in conjunction with the American Fishery Society where we've turned the whole climate dialogue back to the managers and said we're going to let the managers run the workshop and give talks and tell us what they need. We'll talk a little bit about how that's worked in a second.

Each of the subspecies has technical committees and we've done workshops with these various technical committees to talk to them about what we've done with the climate change modeling and then how we use these decision support systems to help them come to some decisions, and I'll give you an example of that here right now. Those are two of the websites that we have.

Steve talked about the climate modeling on his website there and then if you need more information about the products go to this on our website and more of the products and where you can find them are there.

In 2011, Dan Isaak and the Forest Service, USGS, Trout Unlimited, and the Great Northern Landscape Conservation Cooperative pulled together a workshop where we brought in managers and did a two day download of sharing climate information, talking about analysis tools, discussing management implications for climate change. It turned out to be a really nice workshop. That's up on the website. It's got PowerPoint presentations and you can go to the website and pull this stuff up and look at it.

It turned out to be a really successful workshop and a lot of people showed up, brought data, talked about what's going to happen. It was a neat forum for discussing these ideas.

What's next? We have a couple of things that we wanted to share with you and we'll talk about these and then wrap it up here. The first of these is called NorWest, which is a collaborative project with the Great Northern Landscape Conservation Cooperative, Trout Unlimited, us, a bunch of actors up there.

One of the frustrations that we had as we were doing this modeling exercise is that there wasn't a lot of available temperature data all over the western US that we could use to validate the air temperature models that came from the downscaled climate models. As we thought more about it, we were all talking about this idea that it seemed like everybody and their brother was out using ibuttons all over the landscape. These ibuttons were digital temperature recorders in streams to figure out, locally, what their temperatures were.

That turns out to be the data that's available from all the sources that are out there. We've got 45 million hourly records, 45,000 summers, and all this is being collected by various agencies and NGOs and everybody out there. It's amazing how many people are collecting this kind of stuff.

The Great Northern Landscape Conservation Cooperative seeded this project and it turns out it's a $100,000 project cost but the Sensor Network is probably worth millions of dollars because we now can develop models by sub-watershed for each of these air temperature models that can validate what's going to happen with the predictions we've made regarding water temperature.

It's really going to help from the standpoint of more precise bioclimatic assessments for things like bull trout, risk analysis, those kinds of things. The models by watershed are being completed as we speak. For right now, the Salmon River model's being completed. We're working on the clear water and we're going sub-basin by sub-basin across the map that you saw up there. So, a really neat project that spun off of this current project but has been funded by a variety of other sources.

One of the things that James has done, and I talked to you a little bit about this earlier, is in the Colorado River cutthroat trout, in particular, there is a large network of mountain lakes and these mountain lakes could potentially be real key refugia for Colorado River cutthroat trout.

What James is doing with part of his Mendenhall is actually building a model to look at lakes and how important they're going to be for the conservation of Colorado River cutthroat trout. It's really a key piece. In this particular case, it's unique to Colorado River cutthroat, for the most part.

This is what we're talking about. It's a visualization of this that James put together. It's this idea that these lakes could represent areas where we have suitable habitat for cutthroat trout where they don't have to occupy just these high headwaters and there are a number of them within the range of cutthroat trout that include the Uinta Mountains, Green River, all the way up into Wyoming. Pretty interesting idea and I think it’s really worthwhile.

This idea of long term monitoring is really going to be key because we've made a lot of predictions, we've talked a lot about things like invasive species and influence and population response, but what we really don't have is a whole lot of data. When we looked for population response to what's going to happen out here from the standpoint of our predictions, we don't have a lot of good, consistent data everywhere.

These things are going to be really valuable from the standpoint of looking at whether or not we're right. I'll give you a short example. We predicted that during dry years that brook trout in the modeling myth we've done are going to be able to take advantage of dry years because they're going to spawn early in the fall, they're going to be able to overwinter, and then they're going to be able to essentially raise their young and have a leg up on cutthroat trout before they ever get out of the gravel in the springtime.

This year, we went back to three different locations and have seen an expansion of brook trout populations in three different places that we've been monitoring. That's an example of a prediction of whether or not we're going to be able to use this data to say how can we anticipate what might happen and can we provide that information in a timely fashion to managers so that they can use it to do initial attacks or responses on populations like this?

Interesting stuff from the standpoint of “what can we do now to help managers with some of these issues?”

The other part of this is this idea of integrated watershed responses to climate change and disturbance. We've talked a lot about what's going to happen in these watersheds with more wildfires changing flows and all the rest of it, but we really haven't spent a lot of time modeling what those things are going to do. We really haven't thought about that in the way that if we've got small populations where those places are going to be, and potentially, the big hits that these small populations might take.

And then the other part to this is just the idea that we really need to improve the models that we've built because they're based on data that we had at the time, but more data, we're going to have to be able to build better models. And then we're going to be able to inform management decisions in probably a more timely fashion.

One of our scientists came in about three months ago and said "one of the things that is an issue is that all you guys talk about is climate science for my great, great grandchildren, but what about now?" And we really have focused a lot on climate science and predictions for 50 years out or 100 years out, and we started thinking well, OK, can we use some of the data we've collected for things that are much more real time, like now?

And Erin Towler, who's a postdoc with us at NCAR, did a really interesting exercise where she looked at flows in the Big Hole River in Montana where arctic grayling are in the last sort of refuge population. And so the Big Hole Watershed Coalition is a group of managers, livestock growers, NGOs, and their goal is to protect arctic graylings in the Big Hole, and temperature is a serious issue for arctic grayling in the summer time.

So what Erin did was she went to the coalition and said "Well, what do you need to know?" And they said if you could tell us by May whether we're going to have a problem out here or not, then we can go to the producers, the livestock producers, and say "Hey, by July, we're going to need a CFS or two." And so what she did was said "All right. I'll use some of the information we have from this climate modeling exercise and see if I can't get a handle on what things we might be able to do to help."

And what she found was that the May/June precip turns out to be one of the biggest things that you need to know if you're going to try to protect flows later in the year. And she built a simple model, took it to the watershed council, talked to them about it, and these guys are all over it. They really liked what she did. It's pretty simple, but something that helps.

One of the things we're facing in the west all the time now is stream closures in the summer time, because we have high temperatures, streams close off. If our managers know early, then they can alert the public that these things might happen. So it's these kinds of things that we're interested in.

And again, if you look at small populations like the Rio Grande, what are the influences when somebody puts in brown trout or rainbow trout in a place where we have a small population, and how can we assume whether the...or how long are these populations going to persist?

Steve: OK, so this is the last of the modeling. We've come up with this idea that what we can do is actually do near term stream temperature guidance in a probabilistic way. And the way we would do that would be to take our existing models that we've built, of water temperature as a function of air temperature, and perhaps flow where it's important, but there's lots of guidance where we can use our climate simulations, which are about two weeks behind real time.

We have all the SNOTEL and flow forecasts from the NRCS. We have six to ten day outlooks from the Climate Prediction Center on the probabilities of normal, high, or low temperatures, and we have seven day national weather service predictions of temperature. So we're working on a way to combine all of these in a probabilistic way so that we can do some kind of a near term forecast, whether that's 10 days, seven days, whatever, so that we can actually say something about what might happen in terms of the temperature of these rivers in the near term future so that people who are invested in recreation or whatever would have some kind of guidance to go through that process with us and be able to do something about it in terms of thinking about closures and where and how they may have to do it.

This is just the beginning. We're just beginning to do this. The great thing about it is we have a lot of historical data from all these sources, and we can test this thing rigorously to get an idea of how well it may work. We'll skip that one and go to questions.

Emily: All right, well, thanks guys. That was really interesting. Lots of great information and thoughts, and we really appreciate it. The plan is we've got a few folks here in the room, so we're going to take a few questions here, and then we're going to go to the phones and give those folks an opportunity to ask some questions. So first I'll just open it up here in the room and see if anyone has any questions? And Jeff and Steve, if you guys could repeat them if folks aren't near a microphone, because otherwise I don't think the folks on the phone can hear that. So Matt, or do you have a question?

Woman 1: Yeah.

Emily: OK.

Woman 1: When you showed the data for the forest fire and the decline in trout populations from 460 to 191, and I can't remember what species it was, but do you also, when you model, do you look at recovery rates from that? Because obviously, that's caused by increased erosion, warming temperatures because of the buffer of trees is gone, things like that. But then you get a bump after a few years because the downed logs create better habitat as they congregate in the stream and various other things happen. So how do you account for that in the models, that you're going to get a steep decline but at the same time, you're going to get a bump after a few years?

Jeff: You know, it's a real balancing act. Because at the Rio Grande in particular, and that particular watershed, the fragment sizes are so small that you aren't able to take advantage of that bump that you're talking about in a way that you could in larger watersheds where there's more sediment production, more wood, those kinds of things, because you're isolating these fish in very small places.

I worked in southern Utah in three different drainages, where we had fragment sizes that were less than three kilometers long with fishing. At the end of three wildfires, our populations were next to zero. And so from the standpoint of the number of fish that are there and being able to take advantage of that bump that you're calling from the standpoint of increased woody debris sediment and production that typically happens after wildfires, you have to have enough habitat to be able to grow fish to be able to take advantage of it.

So it's that dynamic between size of the fragments and then size of the disturbance. And so in this particular case, it'll be interesting to see whether the bump actually occurs, because that data is from 2011 that shows the decreased population size. Now, whether or not over the next few years, we see an increase, that'll be an interesting question.

Matt Larsen: This is Matt Larsen. Have you had any kind of interaction with the elected officials or the far end of the continuum out in the areas of interest? We have here in Washington. I'm just wondering if you had that out in your region.

Jeff: Matt asked if we had any connection with elected officials regarding some of this work, and the answer to that is yes. We have had a lot of interest from Idaho and Congressman Simpson's office. And in particular, this workshop we're talking about in spring of next year, we've invited Congressman Simpson to be one of the speakers because he's shown an interest in this work and the utility of the work.

One of the things that we talk a lot about to the lay public is this idea of using this information for people to make decisions. Craig Mathews, who's an outfitter in Idaho, wrote a popular article not too long ago, and he said “I've been living in Last Chance, Idaho, which is up near Yellowstone, for 30 years.” He goes “Anybody that doesn't believe climate change isn't real, come see me.”

And that gets legislator's attention, because this guy is well respected throughout the state of Idaho. So yeah, and Senator Tester's office in Montana has also been interested in this work. We got to present some of this to Senator Tester's staff and Senator Baucus' staff.

Matt: Just a quick follow up, I think...they can hear me. You don't have to repeat it. I think Simpson's interested in part because there's a big economic component. Do you happen to know any kind of ballpark numbers? What is trout fishing, recreational trout fishing, stimulate in the Idaho economy or anywhere else out there?

Jeff: It's millions of dollars. If you add in not just the fishing part, but the mom and pop grocery stores, the gasoline that's bought, the lodging, it's worth millions and millions of dollars.

Steve: And you can see the impact of that when they close streams because the temperatures are too high for a week or ten days. People plan their whole summers coming to fish.

Matt: This is millions of dollars in spot location, integrated...does anybody have a feel?

Jeff: You know, it's really interesting as an aside, we are planning an International Trout Congress for 2015, and one of the aspects that we're talking to some people about is this idea of what the socioeconomic value, in particular the economic values there are to the community, and there are very few studies that talk to the idea of total value.

Matt: There's a good Mendenhall project for you there.

[laughter]

Jeff: Take it!

Emily: All right. Any other questions in the room? Oh, OK. Jake?

Jake Weltzin: I'll stand here so people on the phone can hear. This is Jake Weltzin.

Steve: Hi, Jake.

Jake: So I have a question about the long term monitoring, and what's really nice is you've got a very nice framework and show a strong need for the long term monitoring data. Just plug it straight into models, do data model fusion, et cetera. So my question is a bit broader, about the capacity that's out there to create a framework for long term monitoring, that the kind of information that you need. You talked about NorWest.

There should be maybe a SouWest and a SouEast, et cetera, I suppose. But think about it kind of from a biological perspective. What's missing or what would you need to able to ensure the proper data are collected and then made available, say, 50 years from now?

Jeff: There are a number of efforts out there at broad scales that integrate this kind of data. One that USGS is very familiar with is our NAWQA program. That's a good example of how you consistently collect data, the kinds of data that you'd need to answer specific questions. There's the Pacific Northwest Aquatic Monitoring Partnership, which involves a bunch of agencies that have dealt with this particular issue of monitoring over broad scales.

There are lots of frameworks that exist that could be drawn upon if we could all agree on the sets of information that we would like to have.

A lot of this isn't easy. The population information and trying to get folks from individual states to collect data consistently across a broad scale is really a problem that I think we have, but it's one that if we could solve we would have an immensely powerful data set.

Steve: Another issue is a lot of these data sets, for instance the Yellowstone cutthroat data set that we're using, is quite difficult to collect it. We have a post doc doing it now and a crew, a small crew, but they're going all over the place putting in all these sensors in these headwater streams in pretty remote places.

It requires a lot of effort to keep that going. What we found when we did our studies is some of these records are good for two or three years when there's some interest in it and then they're gone. The challenge here, as you say, is to come up with the kinds of data we need but also come up with the system that will support that for long term monitoring. That's always a challenge of all data, regardless whether it's fish or water or geology or whatever it is.

Jeff: That is always the hardest thing to overcome. I've done three or four of these and it's always the hardest thing to overcome.

Emily: I'm going to get one more question and then we're going to go to the phone. Do you mind walking closer to the microphone?

Jim Hatten: Jim Hatten. Question about how will the changing climate shift the advantage to exotic species. It seems like all over smallmouth bass are going crazy and there's many other exotic species. It seems like that could be the greatest threat to these fish communities. What do you see can be done about something like that?

Jeff: Again, it's an issue that we've thought about. In fact, we have a nascent proposal. In the Yellowstone River, they found smallmouth bass about 100 miles downstream near the town of Billings. With changing water temperatures and examples like the John Day River in Oregon where smallmouth bass are everywhere, one of the things we could do is really look at modeling we've done from a water temperature standpoint where smallmouth bass are now and predict how fast they're going to move into the upper system.

It's only a matter of time before somebody introduces northern pike or some other species in the Yellowstone River. I had a call about a year ago from a guy who wanted my support in declaring walleye a native Montana species and I said no, I couldn't do that. There are people out there that are interested in moving species around.

For example, in the Yellowstone it's just a matter of time. I think it's going to be an issue much like it is everywhere.

Emily: Dave, I think that wraps it up here in the room. I'll turn it over to you to do the phones.

Dave Lemarie: Thank you. Right now we have one that's in the chat box. I want to remind folks that are listening in they can type questions into the chat box and I can read them to the presenters or down below the participants list you'll see a bunch of icons and if you just hit the hand icon, that means you're raising your hand, I'll call on you. You can unmute your phone using star six and ask your question yourself.

I'll take the one from the chat box first from Susan Walker. Had a technical question about the ECHAM5 wondering about the resolution for that. She thought it was 120 kilometers?

Jeff: Yes. The native general circulation model run, the global model run that was done is indeed several degrees in resolution. What we do is we use global models like that model to drive our regional model. We're downscaling that from a couple degrees to 15 kilometers. We take the native resolution of whatever global model we're using and use that to make boundary conditions drive our model.

Dave: OK. Larry Zuckerman, you have your hand up. If you could hit star six and unmute your phone.

Larry Zuckerman: I unmuted my phone. This isn't a question. This is just a couple of comments. I used to do Rio Grande cutthroat trout restoration in southern Colorado and, just for clarification, Medano Creek is on the great Sand Dunes National Park. Parts of it are on the national forest. That was a restoration project and it doesn't really have anything to do with warming but the lower end sinks into the sand and it always has.

The other thing is we did have a restoration project right near the New Mexico border way before anybody was talking about climate change and somebody did stock brown trout on top of it. One thing you might want to watch in the different states that are listening is make sure there's a law that it's against the law to stock fish because some states don't have such laws.

Jeff: As you probably know, the restoration project on the Turner Ranch property is probably the largest, at least in that part of the world.

Larry: Sure. What we tried to do in the great Sand Dunes is more than just cutthroat trout. We tried to stick in the native Gila, the Rio Grande chub, and the native sucker, the Rio Grande sucker. It's nice to know the cutthroat is still there after quite a few years. One of the things they noticed that was a real problem was an attitude problem.

Separate from warming temperatures, the rainbow trout and brown trout that serve the guest ranches on the main stem Rio Grande that could be totally suitable for cutthroat trout, people loved the brown trout and rainbow trout and they have no interest in getting rid of them. The Rio Grande cutthroat trout, at least when I was working on them, were always marginalized as non-game fish and not part of the main fisheries program.

It's more of a political management problem than where is the habitat fragmented or not.

Jeff: I agree. We see the same thing almost everywhere. When we talk to the guides association about native trout restorations we talk about eradication of rainbow trout. A typical guide response is those are our money fish. They view rainbow trout, because they jump and fight harder in many cases, is if they can catch one big rainbow trout a day they get a better tip.

We have some work to do regarding the whole native fish/wild trout dynamic.

Larry: Thanks.

Dave: OK, I have another question here, coming through the chat box. I don't know who it's from. It's a two part question. How is groundwater distribution and abundance incorporated into these models, and any indication of the rate at which shallow and deep groundwater will be affected, and at what rate?

Jeff: Right now, these models implicitly take into some account groundwater just by the observation. So in other words, if we have temperature sensors that are sensing groundwater inputs, that comes into play. We do not have yet direct groundwater, surface water modeling and temperature modeling exchanges.

That's a very complicated thing to do in terms of long river reaches. It can be done in relatively short reaches, but that definitely is one of the things that we're interested in looking into when we talk about a total watershed response to disturbance and flow changes. The second part was how is groundwater and recharge likely to change in the future?

Dave: No, any indication of the rate at which shallow and deep groundwater will be affected?

Jeff: Not in the research we do. I think there are people that do groundwater modeling in the USGS that have a pretty good handle on some aquifers in places where they know better. We don't really have that kind of information.

Dave: OK, and then another question from the chat box, from Rick, from your perspective what are the biggest impediments...oops, somebody had another question and it went away from my chat box. Sorry. From your perspective, what are the biggest impediments to developing additional good decision support tools regarding western trout management?

Jeff: That's a good question. I think part of it is, is that the tools that we've developed have been in conjunction with management, but we often don't do a good job of sitting down with the people that are going to use the tools and get a very clear understanding of their interest in those tools. So for example, we can develop a great Bayesian belief network model that works pretty well, but if that's not what managers want, then we've probably wasted a lot of time.

So I think we need to do a better job at the front end of getting input for building the kinds of models that managers will actually use, rather than the things that we think that they should use.

Steve: And I would add to that I think another component of this, that Jeff brought this up earlier, is there's definitely an economic aspect to this, and how much we can do these modeling exercises, and we can look at the potential for change, and we can look at the management interaction, but at some point, management decisions have to reflect the reality of the economic support to make the decision.

So one of the things I think is really important is for us to get some perspective on, for instance, what Jeff was talking about. Do we go for it, and we try to do what we can for populations that we think will be able to be sustainable for long term? Do we make investments other places? So there's a whole other aspect of this that's pretty complicated, I think, to bring into the equation, but it needs to be brought in.

Dave: OK, I have a comment here from Susan Walker. But before we do that, Emily, do you have any more questions from the room there that have cropped up?

Emily: No, I think we're good, so you can wrap it up on your end. I just have a last thing to say.

Dave: OK, I have a comment from Susan Walker, and a quick question from Stephen Hillyer. So Susan's comment is a note from Alaska. We face the same climate effects. Glacier loss, midwinter floods due to rain on snow, increased fire frequency and intensity, summer flow reductions and temperature increases, and non-native species expansions, but not necessarily salmonids, northern pike. And these effects are exacerbated by the fastest effects of warming on the globe, with additions of melting permafrost and adiabotic changes due to melting sea ice.

So in analysis, please do not forget about Alaska. We are in many ways in the forefront of these issues, effects of climate change on fish, and we may lack many of the complicating factors of anthropomorphic complicating factors, such as land use and water use.

Jeff: Can I just say amen to that?

Steve: Yeah, me, too. We haven't forgotten.

Dave: Sounds good. [laughs] Oh, wait, here's more from Susan. In addition, the state is currently planning a very large dam on a pristine river that is likely to exacerbate some climate change effects. The climate change effects on the Susitna River, the National Marine Fishery Service has proposed a comprehensive climate change study for this project. That's it. [laughs]

And then just another comment here, the web address was not visible at the bottom of the screen for information products on your slide there. Information on climate and effects on native trout project. Could you please spell out the web address for the listeners?

Jeff: Certainly. It's http://nrmsc.usgs.gov/research/climate_trout. And I can repeat that.

Holly: We will also be sending out the video in about a week, and I will include those two websites on the email to all of the attendees.

Dave: Thank you for doing that. And then oh, Susan was just asking if we have a list of references cited in this presentation.

Jeff: On the website, the papers that we refer to are all on the website.

Dave: Oh, great. That's a nice recourse.

Jeff: Like I said, there are three of those papers that are due out within the next month, according to the publishers. In fact, we're working on the galleys right now.

Dave: OK, Emily, I've just...there are no more. Well, Steve Hillyer says thanks, but I don't see any more hands raised from the telephone participants, so I'll turn it back over to you.

Emily: Great, well, we have one last question, and then I'll wrap it up. So Laura, take it away.

Laura Thompson: I was just going to ask, you all had mentioned several times about hybridization between the species, and how did you go about documenting...have you documented this or is it mainly just the phenotypes become kind of mixed, or did you actually use genetic information to get that?

Jeff: Both. So the hybridization work that Clint's done has both a phenotypic component to it and a genotypic component. In fact, if you go to the website there's a paper that Clint was involved with with a geneticist that is really interesting as far as being able to use genetics to predict where hybridization might occur.

Laura: Great, great.

Emily: Well, I guess we'll go ahead and wrap it up. Again, big, huge thank you to Jeff and Steve. This was a super presentation. Lots of great information, and it was great to hear all the questions.

I'd like to thank everyone for attending today, and NCTC for your assistance. This concludes our Fall 2012 Webinar Series, but we're going to be starting it up in the spring, so keep an eye out and we hope to have you attending some of those. Thanks again, and have a great day, guys.

Jeff: Thanks, Emily. Thank you, everyone.