"Current Climate Science for Managers"
Jean Brennan Ph.D.
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>> **DAVID EISENHAUER:** All right. Thanks, everybody. This is a great turnout and very glad to see everybody here this morning. My name is Dave Eisenhauer. I'm with Public Affairs here in the Washington Office, and we're very delighted and pleased today to have with us Dr. Jean Brennan, who is currently coordinator for the Appalachian Landscape Conservation Cooperative.

In case you don't know, and I hope you do know, LCC's are the national network of science management partnerships that develop landscape-scale strategies for managing large-scale impacts to climate and other land use changes and pressures.

Jean is in town today, this week, for a meeting of the coordinators, who are also on the Hill today, and so we really appreciate you being here to do this presentation.

Before joining the Fish~&~Wildlife Service, Jean worked as a senior climate change scientist for an environmental nonprofit conducting synthetic research into the impacts of climate change on natural systems and adaptation strategies. She's also worked extensively internationally as a senior conservation scientist for the U.S. agency for international development and is a staff scientist for U.S. state Department office of global change. Jean served as a member of the U.S. delegation to the intergovernmental [indiscernible] climate change and was honored to be selected among a small group of scientists recognized by ITCC for her contributions to share the 2007 Nobel peace prize awarded to the ITCC.

There's a lot more I could say about Jean, but I think everyone is interested in what you have to say today. So please welcome Dr. Jean Brennan.

[APPLAUSE]

>> **JEAN BRENNAN:** Thank you, David. I'd also like to thank the Director for the invitation to come and meet with you and for the endangered species program for the invitation to come and host this meeting.

I'm going to be talking about the aspects of the current climate science, but not really all that in depth. It's the part that is relevant to us as science management entities. So, delivering management based on science-driven information. So it is the climate science for managers, and actually this came out of participation through the National Conservation Training Center, and I'm using their description of that course, which I think helps kind of frame the whole issue here, is that dealing with changing climate requires knowledge and the ability to think about and approach conservation in new ways.

It goes on in the course description to say it requires that we understand the basic science and the assumptions, the implications to our trust resources, and the tools to impact effective management.

So I'm going to use that framework, and as I say, this is going to be the first presentation, and I'm going to be focusing on this aspect of the basic science and our assumptions in how we manage.

What I'd like to do is use this framework. I'm going to discuss 10 key aspects of the science and our need to modify some of our assumptions that we apply in our management objectives. I'll have both the science and the assumptions, and I'll look at them in these three frameworks. Looking first at the climate drivers, looking at aspects of the impacts in terms of the species and community-level impacts, and then look at that in terms of systems level.

So let me first start with some of the climate drivers and what the science is telling us. This is a fairly advanced audience, so obviously the issue of trying to clarify that when we talk about climate we're really not talking about weather, but most of our population thinks of the immediate weather -- I'm here in D.C. in February. It's 66 degrees out. So, climate variability is already very evident.

So the issue of climate is a long-term trend, and generally we talk about that in 25 or 30-year increments to actually talk about a trend in climate. So what I want to do is look at the science that we already know, and that is that climate change is already occurring. What this graph shows is the deviation. So what you're looking at a zero is a baseline, and it's based on instrumented data records over the period of 1960 to 1990. So that's the base, and you're looking at the deviation that from, going back to the 1800s and to current periods. And so what you're looking at is the issue that that from baseline of the '60s and '90 time frame temperature has increased. What's relevant is the rate of change. So regardless of how you look at that, either in terms of a 150-year trend, 100-year trend, 50-year trend or a 25-year trend, what you're saying is the same thing... it's getting warmer, but disturbingly when you look at the trajectory of those lines, that that change is actually occurring more rapidly than in the past, and we as managers need to have that as our foundation of how we manage given that trajectory, that one line.

I will acknowledge that maybe that line's trajectory is a bit naive because I've already shown you that that line is probably going to be modified yet again.

So I'm going to be presenting things just based on the instrumented data looking at a continuation of that trend that we're seeing and asking you how are you managing, how are you planning, how are you developing your recovery plans, et cetera.

The second part of our science is that the change in climate variability, and what do I mean by "climate variability"? Obviously the climate has some range of cold to hot with some average. James Hansen looked at that and tried to describe it in a communication way of just saying, okay, if you had six die and you were trying to present them in terms of that range from cold to hot, this is what they would have looked like in the '50s up until the '80s.

With the increased variability, that means that actually we're taking the present climate and it has already shifted. So we've changed the average and the variance. We've moved that dramatically towards that warmer scale. That means that we're actually going to be seeing less cold weather. We're going to see much more of the hot weather. And we're going to have more record heat in this far extreme. So when James Hansen looked at that again in the communications, he says this is actually what we're now faced with. Looking at those same six die, this is actually the color profile that we're looking at.

So the big question as managers that we're asking ourselves is: When is that fifth die going to change colors? And the issue is that in looking at how those trends are projecting, we're looking at that trend in about 15 or 20 years. What does that mean to the systems that you're charged with managing?

One of the aspects of looking at that graph, that shift in variability and the shift in the extremes, is that we will exceed thresholds for many of the organisms that we are charged with trying to protect or restore. Those especially vulnerable are those that are in unique habitats or have unique requirements, but also the ectotherms, those that required and rely on the temperature for their thermal regulation in terms of the herps and the insects, for example.

When you look at that far part of that range of that record heat in the weather, often people will say, "Well, yeah, it's possible, but it's a really low probability of occurrence, so I'm really not going to be managing for those extremes." Well, we actually have a nice case history not in biology but in the energy sector where the "Deep Horizon" disaster -- the energy sector knew that that was possible, but they said that it was such a low probability of occurrence that they didn't need to put things in place.

So we as managers of natural systems in which extinction has no option after that fact are now charged with looking and managing and paying very close attention to those extremes when you go beyond those thresholds.

One aspect of the changing climate variability is illustrated here in the Gulf Stream. This was actually a very personal note. It was the first -- it was my wake-up call when I learned this story line, the issue that we will have and experience and have seen abrupt changes. This is looking at the Gulf Stream, and actually what you're seeing is how the global circulation of heat moves across the earth. So the heat goes across the African Savanna and then goes into the Atlantic. That then travels up to the north, and it mixes with the Labrador current, and it has a dampening effect. So that's the circulation of hot air to the cooler area.

What that does is it generates a conveyor belt across the globe of the ocean system. So what you have is the Gulf Stream moving the temperature, but then you have what's called a thermohaline circulation. Thermo obviously refers to the temperature.

What's happening is that warm aspect of the stream is moving up towards the north, and the haline refers to salt concentration. When that water moves up to the north, the water density changes. The salt concentration becomes much more extreme and the water actually sinks. In terms of the water basin of the earth, the water sinks down to the floor of the ocean and then travels along that whole pathway. So you're seeing that below and then it comes up again towards the equator, and at the equator it grabs heat and it starts that again. So it's actually moving heat in a water conveyor belt across the globe both under and above. It's two overlying conveyor belts, if you will.

The abrupt change that we have seen, that we have all seen in our lifetime, is that that occurred in the late 1990s, and the issue is that that area, the -- what I'm showing you in gold, that part of the conveyor belt, because of the temperature, stopped. That was the most profound thing for me as a scientist, to think that human activities can stop the ocean was profound, and that is the issue of how changing that water circulation has impact on the biological systems. So that area also happens to be where this triangle, the coral belt, remains as the richest part of the globe. In that event, one-third of coral species were lost. You were all witness to that extinction event, and that continues.

So the issue is that we will have, and we do see these episodes, if they are sustained for long enough periods of time, what happens is you actually do have the slowing or actually stopping of the conveyor belt. That transforms these rich, beautiful, vibrant coral reefs, coral communities into these coral-bleaching events. The coral exists as a symbiot with other organisms, the zooxanthellae that live inside the tissue, and that's what gives the coral their beautiful color. When the temperature exceeds a certain threshold for a sufficient period of time, those organisms leave the coral skeleton and go elsewhere in the ocean's circulation, if they don't go extinct. And as I say, many of them were driven to extinction. So that's why you end up with these skeletal structures, and therefore, all of the plants and marine community, as well as the human communities that rely on those coral systems, are devastated by that type of event. So climate change and climate variability has really profound impacts on systems and also on the economies that many people rely upon.

One aspect of climate change, the changing climate, as well as the change in the variability, is something that we as managers have been taught, that management has been designed and has operated this assumption of stationarity. Stationarity is actually the idea that there is natural systems and fluctuations within some unchanging envelope, that bell graph that I showed you, that bell graph showing you that the variability is the fundamental concept which permeates everything that we do and all of our planning and everything that we've been taught. The issue is that it implies that any variability has a time-invariant probability function. So the issue those that those probabilities and properties can be established and projected based upon the instrumented record.

How many of these events have we seen in the last decade or so in which someone says, "Oh, unusual, hundred-year flood, we haven't seen that," and then the next hundred-year flood occurs in a couple more years. That hundred-year flood, which used to be that extreme variability, that envelope, now has a statistical probability of occurring between every three and 15 years. This is our reality. This is what we see. This is observed. This is not a political statement.

The issue of stationarity, how we manage, how we've been taught and how we have operated is based on this key assumption, and in the 2008 "Science" article that was released, this took all the management community and put them on their ear, that stationarity, that concept is dead, and they were looking at it and talking about especially as it relates to water management and our water reliance. What that means to us as biologists is that climate change undermines the most basic assumption, and that has historically facilitated our management approach, how we anticipate and provide for the supplies and demands and risks. That paradigm is no longer appropriate.

So what I want to do is go back to my little framework and review those drivers of climate. So the science tells us that climate has already changed, there's changes in the climate variability, the assumptions that we must now manage against is that we will exceed thresholds. We will exceed both the physiological tolerance and we will experience abrupt changes, and we must be prepared and be able to account for that. As I said, it undermines our most basic assumption, and, again, the stationarity is dead.

Let me go into the issues of how these impact the species and the community level. and what I want to do is again just show you what is observed, what is recorded, and that in 2006 was a special issue in "Science" looking at all the various organisms already showing the impacts of climate change, that species ranges is changing, and there are systems in which complete biome shifts have occurred, and they continue to occur.

I've been doing climate change communications for about 14 years, and I -- this was one of the first graphs I had always used because climate change was controversial, and I used the Arbor Day Foundation map. There is nothing controversial about the Arbor Day and gardeners and where you plant your winter crops and where you plant your winter shrubs. What was interesting is that USDA Arbor Day Foundation map actually had to be revised in 2006. Those zones no longer applied. You could not tell people, well, that's the good part to plant winter hardy crops or winter hardy garden vegetation. The map had shifts. They now needed to change that map.

This does illustrate, however, those change in state and change in ecosystems. In the south what you're seeing in Florida is you actually have a far greater amount of subtropical climate that has moved there, and in the very far north and parts of Minnesota you're actually seeing we're losing the boreal region out of our nation. So, the issue that species are responding to climate and their species ranges are shifting is true, and we are seeing complete biome shifts out of that.

The Audubon Society used Christmas bird count to also look at that. I use this example for two reasons... one is because it provides very interesting data, and the other is because it relies on citizen science to remind us that we're all professionals and we're all charged with doing this, but it is a task which is far beyond our ability, and we must engage society into this endeavor, and this is an example of one of those.

Christmas bird counts, people go out and just census the birds. They're scrubbed and outliers are looked at, and the data is very much cleaned up, but they looked at a 40-year record for 305 species, and they asked, where is the center of their winter range, has it shifted? And they find the average distance of those 305, if you look at all of them, the average, physical average, is about 35 miles of a shift. 60 of those have actually exceeded that by 100 miles to the north. And then the purple finch gets the award of more than 433 miles.

So, again, species are moving. Our ability to predict where and the rate of change is inadequate. We really don't know that. But we are observing it and we do see that, and for those of you that manage protected areas or refuges, you will experience species moving out and others moving in to those areas.

The impacts of those species' change range has one in terms of disease invasion, and we are again seeing that in the case of honeycreepers, an endemic species or [indiscernible] species that are in the Hawaiian Islands, and the blue that you see here is actually the outlines of a protected area reserve. The two mountains there are high elevations within that island. The red is looking at an inversion layer. So under climate change you have a cloud layer that lays down on top of that mountain, and that actually constrains the tree level. So the tree line is pretty much to that area, and you see much -- a part of the reserve is out of the honeycreepers' access. But the honeycreeper is within that blue, and it's the only area that they are located in that for suitable habitat.

What we now have is an invasion of mosquitoes, which are the disease vectors for avian malaria. They were introduced by domestic birds, or pet birds, from the mainland. The birds came over with avian influenza. Mosquitoes fed on those birds. And then the mosquitoes feed on the honeycreepers which had never before been introduced to that disease. What we now have is, because of climate change, that inversion layer is outside of the range, and we have warmed up the black line, which was the upper limits of the disease vectors, of the mosquitoes. They couldn't go into the reserve because it was too cold. And now it's nice and warm. So, again, those disease vectors are moving into the protected area for the endemic honeycreepers which, again, had never been exposed to those vectors and therefore that disease in the past.

Part of the observed impacts again are the asynchrony of events. So change in phenology. And, of course, you know that phenology is the issue of timing of seasonal events, things like migration or breeding or egg laying, et cetera, and what I want to do is look at one example. This is actually the great tit which is in the European distribution, but it's a good example because it has long-term data. The nest has about 9 to 10 eggs and fledglings, and they go from that egg to that little critter in two weeks' time. Mom feeds each of those little gaping mouths with caterpillars, about 10 per mouth. So, if those caterpillars are some agricultural pest, you can see with the environmental Service of just one little bird picking off all those caterpillars are doing for you. So that's a nice little story. And basically the evolutionary strategy is you are the great tit, what you want to do is you want to have a time where you have your eggs, but when they start hatching, before fledging, it co-occurs with the high peak of those caterpillars. Should be tightly linked to that. But what we're seeing, however, is asynchronous. The caterpillars are emerging faster and earlier, and so you're out of sync and so the fledglings and the nestlings are being robbed of that food source, and many of them are not surviving.

The cautionary note on this tale is not just the asynchrony, but when you look at this one species across its entire range, you don't find that same pattern everywhere. So even when we study and we see an observed change of a species, you can't generalize it across its entire range. You can look at it as diagnostic to what to expect and what to look for.

One other example of that, and that is the caribou or reindeer in our northern states, and the issue is that, again, the strategy is if you're having calves, what you want to do is migrate to when the plants are the richest. New plants are the most assimilable from a digestive standpoint. So the problem is that plants grow according to the temperature. They are queued to temperature. But the herd migration is queued to day length. So it's warmer, the plants are fleshing faster, and then they're senescing. They're no longer being as nutrient rich by the time that the herds get there. So the herds get there, the calves are not surviving, et cetera. And, of course, in many of our Native Americans that are in that region that rely upon that for both traditional as well as subsistence, this has a tremendous impact.

The impact of climate change for us means that we must be managing for disruptive change, both in terms of time, space, as well as the composition of what is the species and the areas that we're managing for.

The other difficulty here, and again that example that we looked at with the Audubon study, is that species move independently. They don't all march up together. And Darwin, you know, who I honor and respect, got it wrong. He had originally proposed that the species would move en masse, the whole system would just move up and down relative to change, and that is not how it works. We see under the warming conditions that you have changes. Those that hadn't been co-occurring now occur, and then in the example here of the sage grouse, in which you're looking at a species of concern, which relies on the sage vegetation, but what's happening is the trees are moving into that and are now crowding out that open sage area and impacting and reducing the nesting and breeding habitat for that already imperiled bird.

And so that issue of species moving in and changing is of concern, but it's not just in the temperate zone. We actually see it in the tropics. In the case of Monte Verde, Costa Rica where you have high-altitude cloud forests, and you have the regal splendid quetzal who lives in those areas and has coexisted since the days of the Mayans at least. It exists on many of their artwork. The quetzal is a very quiet bird, but what has happened is with that inversion layer moving up because of temperature, you are having species move into an area that only the quetzal had been able to survive, things like the toucan, which is an aggressive and -- well, definitely aggressive. Nasty bird. Beats the heck out of all the quetzals. And then you have fire ants moving up there. Fire ants then swarm the nests and eat the eggs and nestlings. So species that have never co-occurred before are now moving in. The quetzal has very little option of how to respond, and they are then co-occurring. This is occurring in a very protected area. We're not talking about any change in habitat fragmentation, et cetera. This is in a high-altitude protected area. And so these changes are occurring.

Under the warming conditions, what you're actually going to have is, and we do see that, species that have never occurred in the past now co-occurring. So our ability to predict what those impacts will be are going to be challenged. This is called a non-analog situation. We have no recorded history, and many cases not even in the pollen records do we know what those are going to look like or how to manage for them.

So to summarize that in terms of the species level, we see change in species ranges. We see changes or even complete biome shifts. We see disease invasions. And this new non-analog species assemblages that we are going to have to start monitoring for and anticipating and dealing with.

What does that mean to the assumptions? Well, we have an assumption about how things interact and the rates of change, both in terms of the communities as well as ecological processes. Many of those are unknown, and the changes are unprecedented. So some of our assumptions are going to have to factor that in. And as John McCarty from Harwood had said, the model of place-based conservation is in jeopardy. So we can no longer -- it's no longer safe to assume that all the species' historic range will remain stable.

What does that mean to us in the Fish~&~Wildlife Service? Well, it has very profound impacts because our historic approach has always been to use a system of protected areas. That dates back to our earliest history as a nation and as a conservation community, back to John Muir and the formation of the National Park System, for example, our creation of the National Forest systems, and even in Fish & Wildlife our refuges and protected marine areas. So we have relied on this issue of protected areas again with that assumption that there is some stability, that issue of stationarity of how we've been managing. What we need to know and acknowledge is that we are in a new era. It requires the landscape-scale conservation, which I hope you can understand why a climate change science is now your Appalachian LCC coordinator working at a landscape level. We must look at systems-based conservation.

So let me go into that last part of it, of the systems-based conservation and look at the systems levels and climate change. Obviously just the aquatic system is one that we're very familiar with, looking at how water moves across that system, evaporation from either freshwater bodies or marine, and evapotranspiration in terms of soil and the aquatic [indiscernible] terrestrial vegetation, moving water from those stores in tissue or in soil and putting that into the atmosphere as water vapor. When you look at the observed changes in the global average air and ocean temperature, this is the ITCC graph showing you just that trend, we are warming it up, and so what does that mean? We're actually charging our hydraulic system. We're actually pumping that water out of the reserves and out of the biological or soil reserves that we have and putting those much more into the atmosphere. The issue is that water vapor is the most powerful and it's a natural greenhouse gas. That means that we're putting those vapors there to help trap additional heat and to further increase the surface temperature. So you see that sort of feedback that we're trying to deal with.

How does that impact the systems, the aquatic, biological systems that we're looking at? Those increased evapotranspirations of streams actually means that you're going to have reduced instream flow. That has many different aspects, but one that we already know is we'll further exacerbate sedimentation and other parts of nutrients or chemical contaminants that are in the water, and they will occur at higher concentrations. When you increase air temperature, you will increase water temperature. It's not necessarily a linear relationship. But you will also with increased water temperature decrease the available oxygen, and that will do several things, both to the organisms that are there, but it will further exacerbate those pollutants which are in the water, and so many of our aquatic systems, our fisheries, will be thus impacted, and it could also have extreme impact on the aquatic species that demand specific flow regimes, and in the case of many of the imperiled mussels which are endemic to the Appalachians where I'm working, that can severely threaten both their feeding and their long-term survival.

Another aspect of that, when we talk about water -- okay, you know water, and you can think about icebergs, and we know that story, and Fish & Wildlife knows this polar bear story very well, but there's the subtlety of water in terms of how it occurs both in terms of its form and, again, that issue of oxygenation. So I'm looking at the golden toad, which is from Panama, which is thought to have been the first species to go extinct due to climate change, and the issue is that in that area you had that same sort of non-precipitant water. So the droplets that form on vegetation or fog belts or the stream -- the splash that occurs from waterfalls, there are systems that are uniquely co-adapted to those very strange parts of how you deliver water that are not in our traditional water, rain and snow. So with rising temperature, again, with the cloud formation that was elevated and many of the amphibians as well as many of the birds in the study of Costa Rica were driven to extirpation, and in the case of the golden toad, thought to be extinct.

So the issue is that we need to look at that in terms of the fine scale of how you define their environment and how you define the water. So it can occur at very low intensity mist or wind-blown precipitation is another part of it. Parts of California have unique vegetation that only occurs there because of these microclimates. So looking at climate change is not just what's the temperature, but it's the microclimate of the organisms that you are charged with managing for and trying to protect... how are they getting their moisture and how are they relying on it and is that changing. So, again, in the case of the golden toad, that was in a protected area. No other human interventions attributed to that.

In the north, what we're looking at in caribou is an increase currently in what's called rain on snow events. So rather than actually having more snow, they're actually having more rain events. That's creating an ice layer for many of those areas. So it means that the caribou are either not able to get through the -- what used to be fluffy snow to get to the vegetation, or in the case here shown, it has actually made it difficult because it's wet snow and not dry snow, they are doing what's called post holing. The energetic requirements for the caribou in each of those steps is like when you go out without your snowshoes. If you're on foot and going through a snow bank, it's a different energy requirement than if you're on dry or if you have snowshoes where you're actually above that. So that's what we're seeing in many of our herds that are, again, being impacted by climate change. They're expending all their energy before they actually go into the spring and have calving. So the populations are reduced.

The other issue, and we talked about this in terms of the aquatics, that you have an aquatic system and temperature changes. In this example of a lake, the fish metabolize and oxygenate, they oxygenate the water, and so there is a settling, there is a part of the lake which is deoxygenated. The subtlety again is the microhabitat. With increased temperature, what's happening is the respiration rate of the fish is increasing. They're actually pulling out more and more of that oxygen at a faster rate, and what's happening is they're depleting the oxygen stores within the same amount of water, they're increasing that amount of de-oxygenation layer, so you have without doing any other changes, you have changed the habitat availability to that creature just based on the change in temperature.

And the terrestrial system, just looked at the issue of change in natural disturbance regimes. The systems are and co-adapted to and were in balance at one time, and, again, the issue, exceeding certain limits. So many of you have heard this story, probably, the issue of the bark beetle. Had a life cycle which went through the first year as an adult laying eggs, the larvae pupate out, and then over the winter, both the larva and the adults, over winter, those that survive go to the second year. The larva again pupate and become the adults and the cycle continues. The issue is that that critical intervening year was required to keep the population, which is a pest population, in check. We're not talking about an invasive. This is a natural system that had evolved. And so with the warmer climate, what has happened is that insect has accelerated its whole life cycle from two years into one. It goes from adult, egg and adult. So not only have you increased the population numbers, but you no longer have those population checks to reduce the population of both the adults and the larva over winter. So, as a result, you have a huge infestation of natural pests that had been part of that landscape and part of that forest, and the bark beetle then burrows in and then can increase the mortality rate of many of the pine species, and this is just one example in British Columbia looking at more than 300 million acres that were lost to that, and the issue is that that has not stopped. It has not been abated.

One aspect that I want to look at is that issue of the limits, changing limits, and, again, up in our north in the musk ox. Musk ox have an internal parasite load that they carry like many wild populations. They shed the ova into the feces and into the ground, and in those hard winters, the ova dies. They're no longer re-infested -- infected by that parasite because it's killed off by the extreme winter. Well, that extreme winter is no longer in place in some areas, and so what's happening is although they have an intestinal parasite load which had been part of their natural cycle, they're increasing their exposure to the parasite because the ovum are not being killed when they are expelled and, therefore, each of those animals are carrying increased loads that they hadn't had before. For females, that has tremendous impacts in terms of their own biological reserves and their ability to carry off a pregnancy or to come into the spring and actually have enough energy reserves for lactation and carrying off a calf. So the population dynamics again due to climate change are being impacted.

One last aspect of that, and in the soil moisture and flammability is something that we know, and, of course, many of our reserves and refuges in the Southwest have experienced that. The issue is that fire is not necessarily attributed to climate change. It's a very complex story. But it is correlated with this increased temperature and these change in precipitation patterns, and the issue is that we have seen these dramatic fire events over the years, but we have seen increased frequency and intensity of these fires, and what I am going to look at is the issue with increased carbon dioxide, greenhouse gas emissions, if you will, you do see an increased vegetation growth, and that is potentially an increased fuel load. The caveat here is that you don't see that in deep forests. You find that in openings. The edge effects or mining roads, et cetera. So although you do accelerate the vegetation, which could potentially increase fuel load, it doesn't necessarily apply for very intact and healthy forests. But on those edges, and as we increase the fragmentation, we increase that possibility. This study looks at just soil moisture. So I said the fire study is difficult partly because of the human impacts and how we've been doing that, and so when they look at the soil moisture and the changing soil moisture over time, what you're looking at is a change in deficits, the loss of that. The redder colors means you had a greater loss in soil moisture. And then they looked at that in terms of how does that impact the types of fires that we have seen. So they then looked at the extent of the fires. The circles don't mean the geographical extent but the intensity of the fires, how many hectares were burned. And so you can see that they are pretty much overlapping in some of those areas where you're looking at the impacts because the soil moisture has been lost and, therefore, you do have that increased flammability in association with the soil moisture.

So in the south the people will say, "Well, they've always had droughts and they've always accommodated for it," and in the case of the cypress and pinyon pines, that is the case. It has co-occurred for a long period of time. But when the drought is of longer periods or greater intensity than they've had historically, you get these events. So the pines do die, and those shown here with them starting to die with the needles turning brown. But because of the extreme and long duration of the drought events that have happened in the Southwest, what you're seeing is a transformation of that landscape. So the trees die entirely, not rebounding, not being part of that drought-adapted cycle. So it was transformed in two years' time from the photo you see in the middle to the photo that you see on the right, and it's always good to remind you that that's not a black and white photo. That is what the landscape looks like.

So, the issue is that those drought stressors will also exacerbate the problem because the vegetation will die off, you'll have increase in the decomposition and possible increased flammability in burning, which will further increase the greenhouse gases. So, again, you're having this accelerated potential of moving the climate impacts as it relates to that.

Many people will say, "Well, there's always been change, species can adapt, can't they adapt, can't we just assume that they'll do that?" We have changed the global mean temperature, and the issue is can you predict that range of extinctions? And just like that one we showed you before, climate variability of some natural range.

Communicating probability to the general public is at times difficult because they don't, you know, do statistics, but we all have kind of an innate understanding of probability. You know, what's the probability I'm going to get arrested -- so we do understand the concept of probability. What I want to do is show you how that mathematically has been translated into what the climate might look like, and this was something that the M.I.T. colleagues had done looking at absolutely no change in how anything was happening, and this was a 2003 study, and the area under that probability curve, they express it as how big of a piece of the pie on that probability wheel, that little wheel of fortune, and then each of those temperatures are given part of the pie. And then they said, actually, if you believe that there's a need to do aspects of climate change and reducing greenhouse gases, you could stabilize by the end of the century at 250 parts per million of greenhouse gas concentrations, or at 360, and that's how many pieces of the pie and what the temperature range might look like. And I thought that was very creative because basically the message was we are gambling with our future, and the question is, again, won't they just adapt? Well, with that scenario, they were hoping to get the global average by the end of the century of a little over 2 degrees Celsius, by the year 2100.

The issue is that in that range systems do have some capacity to move, to adapt, to modify, within those temperatures. When you're in these higher temperatures beyond the 2, and that's why you always heard about limiting greenhouse gases to 2 degrees, is because natural systems have very little capacity to adapt in that range, and the reason for that is you are asking organisms in a 100-year time frame to evolve and adapt to something that they have done but they've done it in examples that are between five and 10,000 year time frames. So our ability for systems and, of course, many of the systems that we are charged with managing, will not be able to adapt to that.

So looking at the systems, we said change in hydrology, change in natural disturbance regimes and the rates of change will actually be beyond the capacity of some systems and some species to adapt. The issue is that we'll have feedbacks and we'll changes which will affect both the structure and function of ecosystems. That has tremendous consequences, both in terms of total loss and biodiversity because it will change the rates and it can change the evolutionary potential and ecological potential, and so the ecosystem services, again, the human dimensions of what the natural systems provide to society and the social benefits, will also be dramatically impacted.

So when you talk to managers and you say, what are you to do with this, well, in terms of the climate drivers, we need to incorporate predictive science into our management planning. At the species community level we need to deliver conservation across the matrix. We need to start looking outside of protected areas at these different land uses as part of the fabric of our conservation of state. And at the systems level we need to plan at the landscape level, and we need to actively engage our nontraditional partners and into broader society to look at them.

If you look at the top of this, and when I started out, I said I would look at 10 key aspects of that, and the 10th aspect is that we shall expect more extinctions. So the question is what is the assumption relative to that? Here's that M.I.T. wheel of fortune, or unfortune, and just to show you that that had to be revised in 2009 because the area of probability of what the temperature was going to look like changed. Without any action it looks like that. If we have some modest amount of policies to change our emissions, it will look like that. So, again, this sort of assumptions on how we work is part of our issues of dealing with that 10th issue of expecting more extinctions.

How will we respond? The issue is we need to be active. We need to be active in terms of our management and in terms of our outreach and in terms of our capacity within our workforce. We need to enable each and every biologist and program manager to start thinking in different ways, to start integrating in those longer term perspectives, and that was echoed -- if you look at the Natural Research Council's report, they stated that the agencies may soon be unable to fulfill their legal and regulatory responsibilities because of climate-related changes.

So the issue is we have a tremendous challenge. We have always had that. But we need to dramatically communicate that challenge to the broader population to understand not only the services we provide but what is at risk.

Do we have the tools to do it? Well, yeah, actually we have many, and they're very encouraging, and as I said, I was invited to do a series, and hopefully be able to present the next part, which is that looking at the planning, the coordination and actually how we would deliver adaptation strategies on the ground. But as a preview, the issue is that what we need to do is look at different spatial and temporal elements in terms of how we do our prioritization. Are we delivering conservation at the most strategic -- when we talk about Strategic Habitat Conservation, it gives that a whole new meaning. We expand the conservation network and partnerships. The LCC's are one of the leaders in trying to help facilitate that. We need to think about the reality that we may need to facilitate species movements or gene flow. We may have to move from this wait and see or passive to a more active role. We may need also to facilitate those change of states. When those ecosystems move out of that, you will have new states moving in. Invasives are going to be the first ones that move in. So we will actually need to actively manage some of those change of states. There is a research agenda laid out, and that will be an ongoing dialogue both within Fish & Wildlife and with our other DOI partners, including the Climate Science Centers. And then we will also be on-the-ground witness to those climate impacts. We must be able to capture and monitor and communicate what those impacts are to provide guidance to our policymakers. We don't promulgate legislation, but we need to provide adequate science-based and observation-based input on how our policies should go forward. The most important tool in that toolbox is the workforce and the ability to transform the workforce into thinking this different way and to looking at different approaches and to actively changing the mode and way in which they do business is really the agenda that we're looking at and the challenge that we face.

So in our charge at Fish & Wildlife of "Conserving the Nature of America," what we know is that conservation in a changing climate means that we can't do it alone and we need to broaden our workforce, we need to engage society, and we need to communicate actively and clearly what this challenge is.

So thank you.

[APPLAUSE]

>>**Eisenhauer:** Thank you very much, Jean. I think we do have some time for some questions from the audience. If you don't mind, what I would like to do, since this is being videotaped, is if you have a question, raise your hand, I'll hand you the mic and you can ask your question, and then we'll just kind of work the room that way.

So, questions? Or comments?

>>**Audience Question:** Thank you very much. That was a great presentation.

So, I work with the National Wildlife Refuge System and have been wrestling with the notion of what we set as conservation targets for our management for 25, 50, 100-year horizons, and the -- do we manage for system processes 100 years out? And what system processes? But I'd like to hear what you think about the different kinds of targets.

>> **JEAN BRENNAN**: That's an excellent question. I'd like to touch on about three different parts of that. So, first, your time horizon, the 25, 50, 100. As a climate scientist and showing you the impacts that I have and showing you the things that have dramatically changed in two to seven-year time frames, my cautionary note is planning for a 25-year or even

a 30-year time horizon makes complete sense. It makes complete sense if you have enough of a monitoring system in place to tell you that that trajectory is no longer going to apply. So I know that in Fish & Wildlife you're familiar with the term of adaptive management. We have to have that as adaptive management turbo style. And we need to put in place the systems that are going to inform you that your planning horizon is solid or not. That's number one.

Number two is that you, depending on the system that you're working with, the issue of looking at vulnerability assessments has often been at the most basic level. Something is not vulnerable simply because it's a wetland, simply because it's, you know, coastal. The issue is that your vulnerability is in context and in a time frame. So, again, the issue of planning and targets have to be specific to the site-based vulnerability, which I would put site-based in quotes because it actually has to be regionally based.

So the refuge system is well placed because many of your refuges are systems already, not just a refuge, but a system of similar types of things, and that should be very diagnostic for you. You should be able to use those and see those trends.

One of the things is that we don't have a common prescription that says, "Okay, they'll all move up north." Well, it's stated that some actually move west. Some move down -- actually some move south.

So, again, the devil's in the detail. So, your planning horizon, the targets that you're going to set, are going to be specific for those things that you are going to be managing for and also the issue of their range change. And, again, those species which are in protected areas, what we see is not a shift, but we see a range compression, a contraction. In many of those things you're losing that southern area. So you're squashing them up there and they're not moving forward. So, again, monitoring that, figuring out whether or not you're having range contraction, and whether or not your systems are actually moving in that area.

Part of -- I've now made it four things -- part of the issue is that how the system will respond is a function of the definition of vulnerability, which is made up of like four little boxes, and there's one little box which is called adaptive capacity. Nobody talks about that box. How can the system or the species decide to change, behaviorally, genetically, reproductively to accommodate those, and we actually see things. In the case of toads, for example, in the aquatic -- excuse me -- the amphibians and reptiles, they can actually change, morphogenesis, they can actually change the rates and things.

So the issue is that making sure on your targets. We are -- we are a species-based, and our legislation is species based, and we do acknowledge as biologists we have to have processes. I hope you saw from the presentation some of those processes you are not going to manage for. You cannot maintain that. What you need to do is facilitate that change and that shift.

So the issue of ***representative species*** which represent the habitat or that ecosystem or the ecological processes might be the more appropriate target. It may not be a [indiscernible] it may be a plant species or, you know, a non-threatened species. But what you need is to have those types of targets that are diagnostic of the process as well as the habitats that you're trying to maintain.

So another process might be for example deposition that create barrier islands, coastal islands, coastal stabilization. That's a process. But you're Fish & Wildlife. You look at piping plovers. You look at those species. You look at nesting turtles. So you are maintaining the process in order to have the habitat in order to have the species which you are required by mandate to protect and that we as society value that.

I think that was the fourth one, the processes versus systems. If we ignore the processes, we ignore the danger of continuing to do what you've always done in a system that is like sand underneath, it's just eroding out from underneath you, and then that issue is, do you live with that reality and manage accordingly or do you calculate how many, you know -- what's that risk, that probability risk, and that's a difficult thing. When you come to endangered species, when you come to populations that are already threatened, we are very much at that little option and little flexibility range. But the refuges are a wonderful stronghold to have the landscape as a foundation to build out that larger network.

So thank you for the question.

>> **Audience Question:** Hi. Actually, I have kind of a related follow-up question. So your presentation talked about how some species aren't going to respond the same way from a phenology aspect and that some are going to be migrating some places, others are going to be migrating elsewhere. So in the case of endangered species, I see the point. I work for invasive species. What happens -- aside from all the other issues in invasive and climate change [indiscernible] when we have species that in one place are important to us but as they start to migrate become invasive to other species that are important to us somewhere else, how do we deal with that?

>> **JEAN BRENNAN**: Again, that's kind of the issue of why we have landscape-level conservation that we're approaching as we look at those multiple dimensions of multiple stressors.

Two aspects of that... when I said facilitating the change, you're right, when a niche becomes open and you have an opportunity, they are invasive for a reason, because, you know, they like those warmer temperatures, they have no competitors, their distribution is faster, not objected. So the issue is invasives will move into those open areas. So if you need to manage to make sure that what you have in that what will be vacant area is of a natural, you will have to actively be doing that.

So a case in point is up in Minnesota, for example, they have an area, and they said, okay, what -- that's a climate envelope model. They said, okay, this is what the temperature looks like, here's the precipitation. If I do that temperature line that continues, what is it going to look like in my 20-year time horizon? And what will that temperature look like? And then where in the earth is already matching that? What is the analogous envelope? And what's there?

So what they do, and in the case I'm thinking of in my mind, is that you're looking at a lot of the prairie grasses, for example. Forested areas going to move out. What's going to move in there? Prairie grasses? Very limited -- very limited seed bank, very limited distribution. So it's actually happening in some areas in that example. They are actively taking seed bank, which is in very small reserves, and planting it right now, and they are creating a seed bank there so that as the temperature changes and as that shift occurs they will have a strong foot hold.

So the issues of invasives are going to be -- are going to be twofold... ones that we've already been trying to tackle, and then anticipating those that would likely move in that we could get ahead of that and actively create that environment that is more natural. And third is to remember on that mixed non-analog species, and we do see that in the Pacific Northwest, we end up with two endangered species that didn't occur that all of a sudden co-occurring and one is beating the heck out of the other one and you're sitting as Fish & Wildlife refereeing this. Well, which endangered species do you want to -- you know. So the issue is that invasive or nontraditional or these non-analog, we might well have species which were not a problem someplace else that all of a sudden just like the toucan became a problem when it wasn't elsewhere. So the dynamics, the cast of characters, the invasive or the villains, are going to change and, again, you need the systems in place to anticipate what might be coming in.

I have a colleague up in Massachusetts works for the state, and he's already setting bag limits for armadillos. He's convinced they're going to be up there. So, anyhow... that that's part of the reality, and you're right, it's terrible -- big challenge.

>> **Audience Question:** Thank you very much for the presentation. Just a follow-up to the refuge question, and it has to do with nonstationary and your comment about looking at systems and processes that are going to change and trying to figure out what's going to tell us what's going to change, and I find it really challenging to get out of stationarity thinking when thinking about what species to pick. So, a piping plover might work, but, on the other hand, if there's warmer breeding habitat or whatever changes in where and how a species migrates if we choose a migratory species, we could end up with a species that simply is doing fine somewhere else, maybe even increasing somewhere else, but we may have chosen it as an indicator for our particular refer usage, and it may not be showing up on our refuge due to changes totally outside our control, and it doesn't mean the process is broken. So I think it's going to be really tricky to think through all aspects of non-stationarity when we look at how to work with processes. Because ultimately, that's what we're going to have left, are processes.

>**> JEAN BRENNAN**: No, I agree, and that's a nice and succinct way of putting that, and the issue there is the recognition of just exactly what you articulated answers the question of why is Fish & Wildlife, why is DOI doing this landscape-level thing? And why are we doing a national network, which is actually not just national, it's actually international. It's precisely that, that, you know, we as scientists have always had our little field site, and now as a scientist I have a much bigger field site. So that's the issue, is that our stationarity, how we planned, how we prioritized, and often how we allocate resources have all got to be on the table now. Business as usual might be at your peril and might be at the peril of your mandate, and so having that broader dialogue and having partners outside of our traditional conservation estate is going to be critical.

So, for example, land trusts, you know, they have lands very important to some of those corridors. Universities -- universities have tremendous land holdings. So we have to really start doing that as well as in industries, and industries, you know, many of them, I've been pleased to see, have been more than willing to engage in those dialogues. So we just have to get out of our comfort zone and get out of our khakis and, you know, straighten up and kind of go into society and engage with that. But not communicating this challenge is our worst flaw.

>> **Audience Question:** Well, thank you. Actually, in a sense, what I was going to talk about, ask a question about, is what Nancy was raising. I just wanted to bring it maybe to the next level in that many of the listed endangered and threatened species, or the candidate species that we deal with, do not exist or only partially exist on any sort of protected lands, be it National Wildlife Refuges, TNC preserves, anything else, and so we're struggling within the

endangered species program of how to deal with that. We feel we have to go well beyond looking at our loan lands or even Federally owned lands to be working with individual landowners, et cetera, but, as you say, the process is so -- I'm still struggling with how to bring that all together.

>> **JEAN BRENNAN:** Again, that refinement of the story line helps, I think. And I think that's part of the issue. You said "We in the endangered species program." Again, it comes back to, yep, can't do it alone. Not only with that meaning your partners that you're engaging with, you need the broader framework, and, again, trying to work at this landscape-level or the LCC-level type of bringing those resources, bringing the dialogue to help in that challenge. It's not your challenge because you can't -- even at a program level we know we're challenged to do that. We need to bring in far more resources within the Fish & Wildlife, within DOI and with our other Federal, state and nontraditional partners. We need to give you support to do that, and we need to help facilitate that dialogue, the needs, that network and that planning at a large landscape level, and, you're right, very much your challenge is outside the protected area. So you're very much in appreciation of the challenge. We just need to leverage far more resources to help support that endeavor, because we know the scope and the scale is already beyond our capacity. We need a different way of doing business, and you need far more support, and I think that the Secretary's vision here is to help deliver that.

>> **Eisenhauer:** Other questions?

Okay, with that, thank you very much, Dr. Brennan.

[APPLAUSE]

I guess I should mention as well Dr. Brennan's presentation in the first of what we hope to be -- having an ongoing series of similar talks focusing on the climate change both within the Service but also within the conservation community at large. So I just wanted to make you aware of that, and thanks again for being here.