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Webinar Transcript

"A mammal's take on the Rapture Hypothesis, Jacob's Ladder, and other notions of doom, gloom, and predictable uniform change in high elevation ecosystems of the Sierra Nevada"

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Ashley Fortune: Hello, everyone, from the U.S. Fish and Wildlife Service's National Conservation Training Center in Shepherdstown, West Virginia. My name is Ashley Fortune, and I'd like to welcome you to today's broadcast of the NCCWSC's Climate Change Science and Management Webinar Series. This series is held in partnership with the U.S. Geological Survey's National Climate Change and Wildlife Science Center. Today's webinar is Part One of a two-part series being presented by Rob Klinger with the Western Ecological Research Center for USGS. Everyone please join me in welcoming Dr. Shawn Carter, Senior Scientist at the USGS National Climate Change and Wildlife Science Center in Reston, Virginia. Shawn, would you please introduce our speaker?

Shawn Carter: Sure. Thank you, Ashley. It's my pleasure to introduce Rob Klinger today. He's a population and community ecologist with the USGS at the Yosemite Field State and has a strong interest in animal plant interactions and emergent properties that come from those interactions. He's been an ecologist with the USGS since 1996 and prior to that he worked for both nongovernmental organizations and governmental organizations, both in the states and also internationally, primarily in Central and South America. So, without further ado, take it away Rob.

Robert Klinger: OK, thanks Shawn. Thanks for attending everybody. Before I jump into the meat of this talk, I think it's very appropriate that I acknowledge and thank the many people and agencies that have been able to keep this project going. First, of course, is the National Climate Change and Wildlife Science Center, if it wasn't for the financial support that they've given us, this project never would have been able to continue.

But, beyond just their financial support, what I've really appreciated with NCCWSC is that, my perspective is that, they're taking the long view on these climate and wildlife interactions.

I think that that's going to bear a tremendous amount of fruit in various ways, for various species and communities down the line. It's been very refreshing to work with a group that has that longer view.

A lot of people have contributed ideas and data and you're going to see a number of these names emerge strategically during this talk and just as we couldn't have gotten anything done without the support of the NCCWSC, we couldn't have gotten anything done in the field without the crew out of Bishop that I've been really privileged to work with over the last six years or so.

Really, you couldn't have asked for a better group of people who went through a heck of a lot to collect a lot of the data that you're going to be seeing in this presentation. So thank you to everybody who's been involved.

Where I'm going with this talk is we live in a very, very, very climo-centric world, if you will. We know darn good and well that our climate has changed and will continue to change. But one of the things that has struck me in this particular environment, it's almost as if 50 or 60 years of ecology seems to have been subsumed under this mantle of climatic shifts. Just because the climate is shifting does not mean that the ecology is going to just stop cold in its tracks.

The big thing is that species' patterns and processes are variable, and they respond in different ways to different types of forces. That's why we have to think beyond just thermometers and rain gauges and packages of often coarse data that fit neatly into these GIS layers. There's going to be some real functional consequences to ecosystems if there are truly major reductions in abundance or major rain shifts in some of these high-elevation species.

And that's really what we're trying to emphasize in this. The modeling and forecasting that we're going to do are usually better when there's a better understanding of the ecological context in which we're doing that modeling and forecasting, and that context just wasn't there for the alpine zone of the Sierra.

I would argue that it's still not there, that we have a ways to go yet. What I'm going to be doing with this talk is I'm going to spend a good deal of time, probably the first third of it, really nailing down the conceptual foundation of the study.

Then I'll move into the data on the mammals, their abundance and habitat association patterns, meadow composite, community composition, some of the temporal patterns that we're seeing in meadow production, and then these plant/animal interaction experiments that we're doing. Some real interesting results with some interesting implications that are coming out of those.

Then I'll try and tie things together and give a little bit of a preview on Part Two. Now what do I mean by part one and part two of the presentation. I'm going to kick that off with one of our closest collaborators, Dirk Van Vuren, out of UC Davis.

At the very get go of the project, Dirk gave us some very good advice. Dirk's been working on high elevation squirrels for a long, long time.

He said, "We just don't know what's going on up there. We better start with the basics." That's what this talk is about. It's about the basics.

I'm going to be focusing on contemporary ecological patterns for these species and one of their critical habitat types.

You'll hear me talk a lot about scale, a lot about interactions, and getting at this notion of feedbacks between climate and ecological processes.

Part two of this talk, which I anticipate being in about a year and a half, or maybe a little bit more than that down the road, will be the modeling and the forecasting.

While I'm going to be throwing a lot of data at you, I'm going to be leaving out a lot of the meaty real technical stuff. That can come up in the Q & A, or probably better yet, give me a phone call, shoot me an email. My contact information will be at the end of the presentation.

We are working in the Sierra Nevada and the White Mountain ranges. There are a few interesting differences between them but it's been a more limited effort in the White Mountains. I'm going to be focusing on the patterns that are qualitatively similar between the ranges on the Sierra Nevada.

We're also looking at five species, one large mammal and four smaller ones and what I'm going to be emphasizing today are the patterns for the four smaller species.

This project was born out of interest, need, and a little bit of frustration on my part. Erik Beever was doing some very nice work with Pica in the Inner Mountain West, showing that they were having good evidence of local extrapatients contracting ranges.

Erik, I think, would be the first to acknowledge this that these results were being extrapolated to other ranges and other species. It was getting pretty frustrating. There wasn't a lot of data to support this beyond what Eric was doing.

I was on the phone one day with Matt Brooks. I was voicing my frustrations, to put it mildly. I said, "Matt, it's like everybody was throwing up their hands and there's this foregone conclusion that these mammals were going to be disappearing off these mountaintops in this rapturous descent into Heaven."

Matt just laughed and goes, "Well, there's your hypothesis, Rob." Matt and I, in a fairly tongue-in-cheek way, coined this term of the Rapture Hypothesis. With apologies to a really great former rock and roll band, REM, I think you know what the scenario is.

The planet heats up. The mammals get trapped up at the top and they start singing these great rock and roll anthems of doom and gloom, but that may not necessarily be the case for all of them.

If you think of this in terms of first principles of ecology and just using the part of science that is a body of knowledge, you have to step back and say, "Well, how likely is this scenario?" The species differ in a lot of ways. The environment varies tremendously. So does that speak for these consistent uniform predictable responses or much more variable ones?

To us, the issues were yes, climate is changing. It's likely going to be unprecedented in recent times but we are not blind. What this figure shows is a well known reconstruction of climate in the northern hemisphere over the last 2,000 years. It was a recent publication this spring that has pushed it back farther.

What it shows is that there's been large fluctuations in temperature extremes for millennia. That means that species and ecosystems in the Sierra have continuously responded to these large climatic fluctuations.

The questions to us have been: 1) how have vegetation communities responded? 2) How have the animals persisted? And really important, 3) how have the animals and the vegetation interacted through what is clearly not an equilibrium system, if you look over ecological and evolutionary time scales.

So, setting the stage for all this, in terms of the data that's available, there's a pretty fair amount on physical processes in the Sierra Nevada. But it wasn't always, or isn't always that straightforward. We certainly know the temperature has increased. That pattern is consistent. But the pattern for precipitation is a little bit more complex. It takes some effort to wade through the data and try and figure out what's going on.

Well, we should have been so fortunate to have such frustrations with the biotic parts. There was very, very little ecological data on animals or plants in the Sierra Nevada. I would say that Connie Millar and collaborator Bob Westfall were the only ones that really were consistently and had been consistently working in that zone. Everything else had been spotty, short-term, very localized.

So we saw this as an opportunity to do good science and collect some information that was badly needed in that zone, and that is really the impetus that kicked off what we hoped would be a long-term study. We're into the sixth year of it. As I mentioned, it's a multi-species study.

The large mammal is the Sierra Nevada bighorn sheep, which is a federally-endangered subspecies. Then the four smaller species that we're working on are the yellow-bellied marmot, American pika, and Belding's and golden-mantled ground squirrel. You're going to be hearing me talk a lot about scale today, and we've designed the project to look at things such as distribution, abundance, habitat associations.

We're not at the demographic stage yet, but we're moving that direction. But we want to look at these different scales, and that's going to allow us to do explanatory models, resource selection, predictive models of species distributions all leading towards this notion of persistence. What is the likelihood of persistence among these species within or across mountain ranges and along environmental gradients?

An area of particular focus for us are these high-elevation, herbaceous-dominated plant communities. Broadly, I'm going to be using the term "meadows" for these. It depends on where you draw your line, but these have disproportionate importance to animals, not just mammals but animals in general, in these high-elevation zones relative to their total area. They make up somewhere between 8 and 14 percent of the high-elevation area of the Sierra Nevada.

The concern that's been is that higher temperatures are going to increase the likelihood of drying in these meadows, reduction in productivity rates and overall biomass production, potentially making them more susceptible to colonization by conifers and other woody species. If these herbaceous-dominated communities transition to woody-dominated communities, this would represent or likely represent a real loss in important high-elevation habitat for many species.

The flip side of this though, something that often gets overlooked, is that higher temperatures could increase productivity. Even through longer growing seasons, higher photosynthetic rates. What this could mean is increased competition for these woody species to contend with, making it harder for them to establish, harder for these transitions to occur.

This is what I call my "late night television slide": "But wait, there's more". There is more. It's not just competition. It's interactions between animals and plants. Animals do modify oftentimes the environment that they live in. Many examples of this in many parts of the world. Functionally, in the high-elevation zone these mammals likely play extremely important roles as herbivores and granivores. We have a lot of data from here and Europe indicating that is so.

So that led us to pose the question, and this is where the functional aspect of the study comes in, of: could the mammals decouple what would be a potentially climate-driven transition to these meadows to force patches through herbivory and granivory?

So putting this in a simple cartoonish but with a little bit of animation sense, you see I call this the typical boring old climate scenario. Rising temperatures and rising ranges in woody species from lower elevations result in these transitions of the meadows to these stable, woody-dominated communities.

Our alternative to that is a little bit more of a complex world, that there's going to be alternative states and alternative pathways to get to these states that result either from the individual or more likely the interactive effects of biotic processes and abiotic factors. So that's the conceptual foundation of the project, so how are we getting at this?

OK, I'm going to probably have to do a quick shift on this slide so you can see the arrows. They weren't translating well. But we're using remote sensing data to look at change in land cover and condition, essentially meadow condition and meadow boundaries over a 40-year period.

We're doing some good old-fashioned muddy-your-boot biology in collecting lots of data from line transect, point counts, and habitat samples on mammal density, their ranges, their distribution, occupancy, and habitat association patterns. To complement the observational data we're doing these field experiments looking at the plant/animal interactions.

OK, here comes a little bit of shift, and then it'll go back to full screen. There are all the arrows. Everything is back. OK, so the data from the remote sensing and the field sewer base are flowing into different types of mammal distribution models, which we're going to be comparing. Then the data from the remote sensing in the field surveys as well as the output from the mammal distribution models is flowing into projected meadow conversion models.

Some of these models are going to be what you often see pretty typically in the literature, ones that are unadjusted. They're being driven by abiotic factors, but we're using the data from the field experiments to come up with ways of adjusting this transition for these biotic interactions.

A little bit more specifically on the remote sensing data that I'm going to be emphasizing in this presentation, I need to give a real shout-out to a climate layer that was developed as part of this project by Otto Alvarez and his major professor Qinghua Quo at UC Merced. I don't have the time to go into the details of this other than to say that Otto avoided a lot of the pitfalls that plagues downscaling efforts.

He basically started from scratch, and he did it in a real thoughtful, thorough way, testing different types of code variants to increase the effectiveness in the interpolation, especially for the precipitation layers. He did an enormous amount of quality control of the data. This has actually been so successful that they're taking this global now.

In terms of measuring changes in meadow condition, we relied on some Normalized Difference Vegetation Index, or NDVI, which is a way of measuring productivity or, in our case, production. This was generated by Karl Rittger, who was then at UC Santa Barbara and is now at the Jet Propulsion Lab in Pasadena, and coordinated by Tom Stephenson, one of our collaborators on the project who heads up the Sierra Nevada Bighorn Sheep project.

Karl developed this layer for 4,700 meadows throughout the Sierra Nevada. We're using data on 3,500 of those. These are bi-monthly values going from April thru October from 1990 to 2010 at a 30 meter resolution. A very powerful, large data set.

In terms of the field survey data, the core of it were our land-line transects. These things here that look like intestinal parasites are the locations of the transects. We have 21 of them throughout the Sierra Nevada. This is very extensive sampling. It spans about three degrees of latitude, captures about 90 to 95 percent of the Alpines in the Sierra, spans an elevation gradient of about 4,500 feet.

These transects are 10 kilometers long. They've been sampled from 2008 to 2012 three to four times a year. They were selected from a pool of a little over 60 potential routes and each transect has 10 point count stations that are randomly located along it.

We also have done an equal amount of extensive and intensive habitat sampling, too, vegetation sampling, if you will. Over 250 plots have been sampled between 2010 and 2012. As with the mammal surveys, this is intensive data as well as extensive.

The field experiment, I'll get into the details of the design a little further on into the talk, towards the end of the talk. Basically, this is your classic exclosure study where we've done seeding as well as seedling plantings inside and outside of exclosures, so essentially manipulating delivery as well as seed density and then measuring various factors and looking at seed germination and survival of seedlings inside and outside those exclosures.

I've been talking about scale and I'm going to continue to talk about scale so I need to define that a little more explicitly. When I talk about the range-wide scale, we're talking about the mean value of some variable across our study area. When I talk about the regional scale, that's based on the transect on the order of 10 square kilometers. That's based on the linear distance of the transect, 10 kilometers, and a one kilometer belt on either side of that transect. At that scale, we have almost 10,000 observations that we've collected over the five years of the study.

When I talk about local scale, now we're at the hectare scale. 20 hectares, 250 meter radius around each of our point count stations. We've collected a little over 5,000 observations at that scale. Then the patch scales, which are the geo-referenced locations of the animals we observed in the field. It's about a half-hectare scale. We've got about 8,700 observations at the patch scale.

Let's get into the data now. If we were to see consistent responses among the species, there were five general conditions we would expect to see met. Environmental variability would likely have to be low. We would see some pronounced structuring geographically in their distributions. Also, some correlation, spatial and temporal, in their abundance patterns, both for species and assemblages.

When I'm talking about an assemblage in this presentation, I'm talking about the combination of species, so species identity and their relative abundances, at a particular scale. Then the species would need to be restricted in habitat breadth and have similar habitat use patterns. Let's start working through these systematically, starting with environmental variability.

We have three general data sets, three classes of data, that we're using for these environmental analyses, these relationships. We have a climatic data set, we have a land cover data set, and a topographic data set. What we did, after looking at some correlations and pairing them with variables, looked at these environmental conditions here at the regional scale, so each of these points represents the environmental conditions for multiple variables for a transect.

Principle Components Analysis, quite a good one, explained almost 70 percent of the total variation on the first three axes. The thing that jumped out of here is you don't see real pronounced clustering. As a matter of fact, you see a lot of scatter throughout environmental space. In other words, the environment is extremely variable. The gradients that we're picking up are not simple ones. They're very complex. You have multiple variables from each of those variable sets defining those gradients.

Interestingly enough, climate accounts for less variability overall than topography and vegetation. You have this highly variable environment of which climate is not necessarily driving the bulk of that variability.

Shifting over, now, into mammal abundance. Start off with a real simple diagram for each of the four species over time at the rangewide scale. This is their density, the number of individuals per square kilometer. I show this mainly just to show a very simple pattern. Because, if you parse down, if you go down to the next scale and look at what's going on regionally, we're still at the number of animals per square kilometer, you get a lot more dynamic view of what's happening with the abundance patterns for these species.

We see the same thing at the local scale. A nice, neat, clean rangewide estimate, density per hectare, animals per hectare, that is obscuring some very strong dynamics at the local scale. This is one of the things that really jumped out at us is that these large scale patterns, here I've simply transformed the inter-annual rate of change, these large scale patterns are masking these incredibly strong spatial and temporal dynamics.

It's not just in magnitude, it's in direction as well. So that between any two years, you can see increases going on, you can see decreases going on, you can see stability. It's magnitude and direction. A lot of people would be tempted to write this off as noise, but we're saying wait a minute, this might actually be the ecologically relevant pattern. This is what we need to be paying attention to.

In terms of the geographic structure, here we've got the structure for each of the four species. Here's latitude, here's longitude, this is their density, and this is their variation in density. If we saw strong geographic structuring, you would expect clustering of points for different levels of density or variation in density in different geographic regions.

But, what it looks like is more of a shotgun pattern. We see that, as well, at the more local scale. We can test this statistically using some spatial statistics. We can actually quantify how much structure there is. We have four species, we have five years of data on each of these species. What we were looking for, if there was supposed to be some kind of consistent response, is positive correlation of abundance with geographic distance and that would be over a long geographic distance.

What we see, instead, is this statistic, Moran's I ranges between minus one and one, is all of the correlations were negative. They were all less than zero. This held both regional and local scales. A little bit more of a complex pattern for the assemblage, but we can, again, look at the composition and relative abundance of those assemblages with geographic distance using a Mantel statistic. This gives the correlation in species identities and relative abundances over geographic distance.

What we see are two positive correlations. One about one kilometer away from each other, another about 18 kilometers away. We also see two negative correlations between 8 and 12 kilometers away. There's absolutely no correlation as you get farther away from 20 kilometers.

What this is saying is that the assemblages are similar within about a kilometer of each other and then maybe a watershed away that has similar environmental conditions, but, also, there can be a lot of dissimilarity between those assemblages within a few tens of kilometers of each other.

This is the big one. The correlations, be them positive or negative, are all occurring within essentially 12 miles of each other, not beyond that. The message here is that there is minimal geographic pattern in density or the variation in density. The correlations in their abundance patterns are inconsistent and they're certainly not very extensive. A lot of this is probably being due to these highly variable spatial patterns that we're seeing in abundance and the temporal patterns.

Now let's look at some of the habitat associations. We're going to start among the species and we're going to look, again, at three scales: regional, local, and patch. We have abundance by transect data, we have abundance by point data, and then we have the incidence, presence/absence at geo-reference location for which we've got vegetation data for. Again, our three general environmental data sets and our goal is to find the most parsimonious set combination from these that intersects variables that explain the most variation and distribution abundance patterns.

Starting at the regional scale, each of these points represents a transect in a particular year. The species composition, the relative abundances in that year. The first thing that you notice is you see a lot of these mixings of transects in years and environmental space. You don't get any discreet clustering either spatially or temporally in this.

For the most part, you see separation of species in environmental space, although the marmot and the pica are fairly closely associated with each other at the regional scale. Keep that in mind. The species are aligned with different environmental gradients and in this parsimonious set of variables only one climate variable was retained. The rest came out of the land cover and topographic data sets.

Going down to the local scale, again, we see a real mixing of the points in environmental space. The species continue to be separated, for the most part, in environmental space, but now notice, at this scale, the associations have changed. The marmot and the Belding's ground squirrel are more associated at this scale than they were at the regional scale and the marmot and the pica are quite separated in this scale where they were more closely related at the regional scale. Again, the species are lining up on different environmental gradients. The climate variable is still completely out of this set at this scale.

Going down to the patch scale, now we see complete separation of the species' environmental space. Of course, they continue to be related to different environmental gradients and, again, only one climatic variable is retained out of the set of the original 21.

Now let's shift over a little bit and see what their habitat use patterns are and how selected they are. Starting off with use, we're going to have two indices of habitat selection that we're looking at. The first one, which is abbreviated, the symbol is B_i, is the index of relative habitat selection. It scales between zero and one. The closer to one, the higher selection for a particular type. We have half a dozen general land cover classes.

What you see, not so much because of selection, of course we expect this, but each of the species, each of the four species, is using several different of these land cover classes. That indicates that, yes, they have their preferences, no surprise there, but they're not necessarily that restricted in their habitat breadth.

Now let's shift over to the absolute index of habitat selection. If the 95 percent confidence intervals for this index overlap one, that means that they're using this particular class pretty much in relation and proportion to its availability on the landscape. If it's above, that means they're selecting for it, it's used disproportionately more than its currents. Below the line, that means that they're selecting against.

What we're seeing, and I'm using the marmot and the golden mammal ground squirrel as examples here, is that there are these inter-annual shifts in the magnitude of selection, even in habitats that are clearly favored, land cover classes that are clearly favored by these, you see these shifts in magnitude. Sometimes, for some of these classes, with all four species, you would see disproportionately more use in one year, disproportionately less use in another year, and then proportional use in another.

The notion here, the message is that they're not that stable in the magnitude of selection over time. We can ask do we see the same thing spatially? Using the Belding's ground squirrel and the pica examples, what you see is from transect to transect to transect, again, shifts spatially in the magnitude of selection to the point, for example, here with the Belding's ground squirrel, along some transects they use shrub dominated areas pretty much in proportion to their availability. In other areas, they avoid them, but in others they're found disproportionately more in the occurrence of shrub on the landscape. We see these patterns for all four species.

What seems to be going on, I'm using the marmot as an example of this but, again, it holds for all four species, is that the proportion of different habitat types shifts from geographic area to geographic area. They can adjust their selection behavior. I'm just showing two positive relationships. Not all of the relationships are positive. Some are actually negative. Habitat selection does seem to be varying with availability. They're shifting their behavior.

Now we can revisit these five conditions. Is the environmental variability low? No, it's quite variable. The species aren't very structured at all in their geographic distributions, they're very patchy distributions. There's very inconsistent low and often in the opposite direction of what is expected in the geographic correlation of abundance.

The species don't seem that restrictive in habitat breadth. They are, for the most part, facultative specialists. Use varies temporally, and they can shift the selectivity among regions. They certainly are different in their habitat use patterns, and that can also vary with scale.

Now let's shift over and look at the meadow structure and condition, this important habitat. What I haven't mentioned up until now is look at their habitat associations. Out of those half a dozen general land cover type of classes, meadows were the only ones that all four species used at least in proportion to its availability on the landscape. A number of them, especially the marmot and pica, consistently used it more than its availability on the landscape.

Needless to say, this is a very important habitat type, as we suspected, as we knew anecdotally, for these species. It would be useful to know what is driving species composition in these meadows so we can incorporate that kind of information into the modeling and the forecasting that we're doing.

This is something that Jen Chase and her office here in Bishop has been leading. Her and I have been working on it. We've taken a metacommunity approach.

We're looking for evidence of the four processes that are typically considered to be what maintains metacommunities. What we expected were very strong species sorting along environmental grades. In other words, a lot of turnover in species composition along gradients that we figured would be related to the climatic variables. We also expected some dispersal effects.

Again, we had our environmental gradient data, we had the geographic distance among all pairs of plots. We had 160 meadow plots that we were using in the analysis. We did two types of multi-varied analyses, and I won't plague you with their very long names, but these are very efficient analyses because it lets you look simultaneously at turnover along gradients and what the effect of dispersal is on composition.

Boy did we have some surprises coming. First of all, looking at an index and similarity in species composition, this is a presence, absence one Sorensen similarity index scales between zero and one. It's the same for other indices of similarity, as well. Even when environmental distances were very close, very similar environmental conditions, you had very, very dissimilar species compositions.

Each one of these points represents the pair-wise comparison among all of those 160 meadow plots. We saw that geographically, as well. A pair of plots that were a couple hundred meters apart from each other could be as dissimilar in species composition, on average, as if they were 20 kilometers apart. We expected about half of the variation in plant species composition in these meadows to be explained by environmental gradients, but only about 10 percent was. An equally low amount of that variation was being explained by these dispersal effects. There was a lot of residual variation.

Where we expected to compare the species abundance distributions to this neutral model, a null model, just to show how different it was, this is where the biggest surprise came. The pattern was consistent with expectations from neutral processes. If you looked at the observed and the expected distribution of species, either by frequency of species in different occurrence classes or as a cumulative probability, they were very, very, very similar.

This is indicating that local conditions and what are known as priority effects, essentially who gets there first, is really responsible for a lot of the meadow composition. That leads to the question if communities have assembled locally in these meadows would we expect them to not reassemble the same way if there were changes? An open question.

Then, of course, we want to know how about the condition of these meadows? Are they getting less production? This is where the NDVI data came in. The first thing we wanted to do is make sure that NDVI was actually tracking herbaceous biomass. We did a simple regression on that and we were very relieved to find that it was. This is the herbaceous biomass data from our vegetation plots against different measures of NDVI and we got these very strong correlations.

We also wanted to make sure that these GIS layers that were saying that a particular class was dominated by herbaceous vegetation really was and so we did some confusion matrices of what we saw in the field, what the GIS said. We were, again, relieved to see that, yes, our assumptions are being met. These are being mapped pretty accurately.

What is that temporal pattern? We can look at the minimum NDVI, the mean NDVI, and the maximum mean NDVI per meadow per year. This is using generalized additive models which were a very effective way of looking at variation and time series data.

We also had an interesting statistic that we calculated, the coefficient of variation of NDVI. That's a measure of the spatial heterogeneity within these meadows. If they were drawing, we expected that coefficient of variation to be large and to increase. What we saw instead was that it was very small. There was very little heterogeneity within these meadows with the NDVI data. For all four measures, what we saw was a heck of a lot of variability but not much trend.

What trend we did see was with minimum NDVI and that was not indicative of drawing. It actually appeared to be increasing. Another way of looking at that is simply to convert these values into inter-annual rates of change. What we saw was fluctuating in a highly variable fashion around one.

Pulling this together, production in meadows over the last 20 years has been highly variable, but there's no evidence right now, that we can detect, of a decreasing trend. For the animals, what this implies is, in terms of potential forage amount available to them, it's been pretty stable. It might even be improving in some ways.

Now we'll get to the field experiments. We had the assistance of hundreds of thousands, if not millions, of mosquitoes to set this experiment up, of which, of course, we were eternally grateful for their help. We got this set up in August of 2011. What this consists of, two sites, one in Yosemite National Park and the other in King's Canyon National Park.

At each site, we have three arrays. What the arrays consist of are these combinations of seeded or unseeded within an exclosure or outside of an exclosure and five different seed densities. We also jump to the next life history stage and planted 84 seedlings. Now we're able to look at germination rates and seedling survival inside and outside of these exclosures.

What we find is quite striking. In the first year after the initial seeding, this is within exclosures, this is outside of exclosures. We see three to five times as much germination within the exclosures that are protected from herbivory or granivory as we see on the outside. Each of these lines represents one of those different seed densities. There is density dependence, at least within the exclosures. The real story is across densities you see higher levels of germination.

Typically it's been said, I've heard this over and over again, what matters for germination of woody species in these meadows is soil moisture. Yes, that's true, but they have to get past the mammals first. There is a soil moisture effect. There is also a competition effect, which I'm not going to get into.

We can jump to the seedling life history stage and we see the exact same thing. In the first four months after planting the seedlings, there was 88 percent mortality, and that went to 100 percent a year afterwards, outside the exclosure where there was only two and a half percent mortality within the exclosures. Pictures here of a Belding's ground squirrel and a marmot, each either in the process or after chowing down on some seedlings.

We said OK, this is interesting. That's great. That's experimental data. That's from two sites, essentially. Is there evidence that this could be going on at a larger scale? What we did is a decay analysis looking at the distance from the closest colonizing source, a patch of krummholz, a patch of conifers, if you will. What we would expect, if herbivory and granivory weren't important, is that these reverse J-shaped curves for all pre-life history classes, but that's not what we see.

What we see is low or no numbers of seedlings and no decay of the counts over distance. That is implying that distance matters, but so does granivory and herbivory. What we're seeing is a little bit of a disconnect over time. A seed and a seedling escapes predation and they accumulate, typically, close to the colonizing source over time. But, the seedlings themselves, probably the seeds and the seedlings, are getting hit very hard close and far away.

Jen Chase and I are calling this the “Gauntlet Hypothesis”. We're putting it in the vernacular, anthropomorphizing a conifer as asking, "What the heck have I got to do to get established in these Alpine meadows?" Steven Ostoja likened this to a sieve. It's an ecological filter. First you've got to get there. That's dispersing from a colonizing source. The second probably biggest hit is you can't get munched by a marmot, pica, or ground squirrel.

The third hit is you can't dry out and the fourth hit is you can't get beaten up by those herbaceous neighborhood bullies. It is tough to get established in these meadows, at least in the Alpine zone.

Let's start pulling this together, now. Some early interpretations. As I said earlier, we're very, very interested in what others consider noise. The mean response is probably much less informative and meaningful. It's what's going on at the regional and local and possibly even patch based scales. We need to integrate this type of data and this type of information into the dynamics of the models in the forecast that we're developing.

The mammals don't appear to be simply waiting around to be victims. They can adjust their habitat use and there is this evidence that they are managing their habitat, if you will, through herbivory and granivory. This just does not speak very strongly to the likelihood of uniform responses throughout the Alpine zone. There's a heck of a lot of heterogeneity already in the environmental conditions, mammal distribution abundance, and the key habitat type.

This is implying to us that we might better expect areas with a high and low probability of persistence. There's some caveats and some implications that go along with these interpretations. One is that, simply, we have not reached a climatic state yet where we're seeing large changes. These transitions could also be very rapid. This notion of thresholds and tipping points rather than more declinal, gradual change.

The patterns that we're seeing in the Alpine zones and the very upper part of the sub-Alpine zone probably does not hold in other elevation zones. Kaitlin Lubetkin, who is a PhD candidate at UC Merced, is doing some very nice experimental and observational work in the sub-Alpine zone and she's getting very different patterns than we are, but those patterns start falling apart as she pushes up towards a treeline and our patterns start to fall apart as we push towards a treeline.

We're going to start working together on this to get a little bit more clarity on how far we can extrapolate results in these different zones.

Change is happening, yes, but change is not necessarily synonymous with disaster. But, if there are wholesale shifts from what we're seeing in our data, that has some very profound functional implications for what is going to go on in the vegetation communities in the Alpine zones.

Right now, what we think is happening is that these little windows of opportunity during a year or series of years when mammal abundance is low, that conifers could, potentially, get established in the meadows. If there's drastic changes in abundance, if there are big changes in range, those windows of opportunity might open up to a full door.

We plan on continuing our field experiments. We're going to be doing a lot more analysis of the ecological patterns. One of the things we're particularly interested in is comparing models with GIS data with data that is not typically suited for GIS and see which is more informative. Of course, we're going to continue working on changes in meadow structure and function.

With the modeling, one of the things that we plan on doing is making sure that each of our models also has an uncertainty layer with this. Otto and Qinghua, UC Merced, and I have talked about ways of doing this, way of spatially partitioning, temporally partitioning, and spatio-temporally partitioning the data to get at this notion of how to generate uncertainty layers, quantify just how good these models are that we're building.

We're doing the same type of things with predictive RSF, Resource Selection Functions. We have a very, very nice example of that that Alex Few is working with the Bighorn team, Tom Stephenson's team, is doing with models being developed for the bighorn sheep. Then the modeling of the meadow dynamics which, as I said before, is going to be really tricky. It's going to take some time and some thought to do a good job on that.

Are the Alpine mammals doomed? Is Jacob's ladder going to descend out of the skies and is there going to be a wholesale rush of these hairy, high elevation creatures getting away from these hot temperatures and heading to a cooler but better place? Or are they going to be singing a little bit different tune, adding some lyrics to REM's song of doom and gloom? Yeah, it's the end of the world as we know it in some places, but there's trade-offs and some things are going to happen in some ways in some places and in other ways in other places.

With that, that's my contact information. I think that we're now open for a Q and A session. Ashley, is that right?

Ashley: Yes. Thank you very much, Rob. Great presentation.

Robert: Thank you.

Ashley: We are now open for questions. All right. Our first one will be from Toni Lyn Morelli.

Toni Lyn Morelli: Hi, Rob. [laughs]

Robert: Toni Lyn, how are you?

Toni Lyn: I'm doing [laughs] great. Good talk, really exciting to see, and it's just incredible how many different aspects you've taken on with this research. It's really awesome, and I'm looking forward to the years in the future, too. I have a question I'm thinking about. You're talking about the species. You're looking at being speculative specialists. One thing that strikes me is perhaps seasonally they are but most, I guess, probably all four that you're thinking of. You're looking at and you're talking about today, have very important habitat requirements in the winter.

Some of the work that we've been doing or been thinking about focuses on the impact of warming, in terms of snow pack and how the hibernators might be starving to death during the winter and in the early spring.

You can imagine pica also have important habitat requirements in winter. So is that something you're thinking about?

Robert: Yeah, it is. When we're developing the models, it's probably going to be fairly parallel to some of the work that you've been doing is that issue of the insulating properties of snow pack but we also want to incorporate the potential nutritional aspect in those types of models. And that's because yeah, they might lose some insulating properties, but they might make it up in terms of increase forage availability but yes, it's definitely something we're thinking of and it's something that we hope to be incorporating into those models when we develop them.

Toni Lyn: Cool, thanks, looking forward to when more results come out.

Robert: Be patient. [laughs]

Ashley: We have another question from Erik Beever.

Erik Beever: Excellent job, I echo, Toni Lyn's comments. It was neat that you included a lot of different aspects. My question is about scale, and could you maybe talk to, particularly relative to the habitat associations and the resolutions at which we should think about those at the various scales of analysis, particularly down at the lower scales? Can you talk about how those are meaningful in terms of what distances these animals move and how you calculated those associations in terms of how fine they were?

Robert: OK, I think I see where you're going with this. In other words, how did we come up with, say, a 10-square-kilometer or a 20-hectare scale?

Erik: Correct.

Robert: OK. So what those were based on were the sighting distributions of the animals along the transect and at the point counts. We got into the literature, and particularly with the marmot, they can have some pretty long dispersal distances. And so it seemed like based on the sighting distributions for these species that these were the most meaningful distances that we could come up with. Now, that being said, what we're going to be doing with the modeling, and this is where that patch base and I think where you're going with your question is really going to be important, is we have these precise geo-reference locations. And around each location, we're going to be developing models based at different distances for species. So where pica is more limited - you know, its home range is probably on the scale of a few hectares; maybe a couple might have tens of hectares, although I doubt that - whereas a marmot might have a much larger home range. We're going to look and see what the different predictions are as we vary that scale from those patch-based locations.

Erik: Great. Excellent. Really quickly too, did you see the same kinds of patterns, in terms of, most of the variance went to residual or unexplained variance, if you used a different index of similarity?

Robert: We used...

Erik: ...Sorenson's?

Robert: Yeah, we did Sorenson's, Jaccard, and Morisita-Horn, and of course Morisita-Horn takes into account the relative abundance, whereas Jaccard and Sorenson's it's just based on presence/absence. And absolutely, yes. We saw that same rapid drop-off both environmentally and geographically in similarity.

Erik: Excellent, thanks. Great work.

Ashley: Thanks Erik. We have another question from Chris Hoving.

Chris Hoving: Hi Rob, my question has to do with if you have put any thinking towards carbon dioxide fertilization and the affects that might have on productivity in these meadows?

Robert: That's a really good question, Chris. Yeah, we have thought about it but we haven't gone down that route yet. We doubt that we're going to for now. We've got enough on our hands with the data that we've collected. We want to get a handle on that. Then in the future, if we can start getting into those kinds of questions. Yeah, nitrogen deposition, is another one that we've been thinking about.

We've broken our modeling scenarios into first generation, second generation, and third generation. We see those kinds of questions probably being third generation questions for the modeling.

Chris: OK, thank you.

Ashley: OK, thanks Chris. Do we have any more questions out there? All right, Rob, do you have any closing remarks?

Robert: No, I think I've talked enough today.

Ashley: [laughs] I would like to thank you again for a great presentation.