Climate Webinar – May 29, 2014

Thank you everyone for standing by, and welcome to our May webinar entitled 'Climate Change Impacts on Wildlife'. These webinars are an initiative of The Ohio State University Climate Change Outreach Team, a multi-departmental effort within the university led by Ohio Sea Grant, Office of Research, Ohio Supercomputer, OSU Extension, and eight other OSU departments to help localize the climate change issue for Ohioans and Great Lakes residents. I am Jill Jentes Banicki from Ohio Sea Grant and Stone Laboratory, and joining me today are two scientists, Dr. Ben Zuckerberg and Dr. Amy Iler. Dr. Zuckerberg is assistant professor in the department of Forest and Wildlife Ecology at the University of Wisconsin-Madison. Dr. Zuckerberg received his PhD from SUNY College of Environmental Science and Forestry, and later served as a research scientist at the Cornell Lab of Ornithology. His research focuses on how climate change and habitat loss impact wildlife populations. We're really happy to have him here today.

We also have Dr. Amy Iler, who is a post-doc research associate at the University of Maryland and The Rocky Mountain Biological Laboratory. Currently, she is studying how climate change affects the timing of flowering plant population dynamics and hummingbird migration in the Colorado Rocky Mountains. We're really delighted to have both of them here today to talk with us about climate change impacts on specific wildlife species and wildlife in general.

But before we start a few logistical issues. During our presentation all participants will be in a listen-only mode. Afterwards I will conduct a question and answer session. If you would like to ask a question during the presentation please feel free to use the 'chat' feature located on the right-hand side of your screen, and I will collect and pose your questions out to both at the end of their presentations. We have over 200 participants on the webinar so far, a great diverse group representing governmental agencies, academia, and nonprofit groups from the Great Lakes and around the country. Please keep those questions coming throughout the presentations, and we should have a great Q&A session. As a reminder this webinar is being recorded and will be posted onto our website for later viewing. Also, we will post a webinar survey in the 'chat' feature towards the end of the hour. Please take a few minutes after the webinar to fill out that survey. It will help us continue to bring you better webinars. So without any further delay I'd like to introduce Dr. Ben Zuckerberg from the University of Wisconsin-Madison who will present 'Assessing the Vulnerability of Wildlife to Climate Change'.

Ben, you should be all set.

Wonderful! Well great, thank you very much for this invitation to speak with you today. I'm really looking forward to it. And speaking with both Amy and Christina about what to cover today, I'm going kind of talk about what I see about is being the major impacts or ecological impacts of anthropogenic climate change. And in doing so this is obviously a very wide-ranging topic with numerous examples in it, and I'm really just going to kind of take a couple of sort of examples of current research that we have ongoing in our lab, and in doing so I'd like to kind of rightly point out a couple of my coauthors, Kariné Prince and Lars Pomara, who are post-docs in my lab. And so much of what I'm going to show you today is parasitizing a lot of their current research.

So I'd also like to acknowledge several of our funding sources. A lot of our work are funded by Landscape Conservation Cooperatives and the Northeast Climate Science Center. And then also we spend a lot of time working collaboratively with a number of state agencies to try to really understand basically climate change vulnerability; what species and populations are most vulnerable to the impacts of climate change. And so I'd like to acknowledge many of those people that we work with.

As we all know this webinar is focused on trying to assess or really reviewing the information on climate change. I'm not going to go into this too much other than to say that certainly what we've been able to document in anthropogenic climate change is pretty impressive in terms of rising global temperatures, shifting patterns of precipitation, attenuating winters in the northern hemisphere, the early onset of spring, potentially higher frequency of extreme weather events, and of course ocean acidification. And as I mentioned I'm not going to talk about these trends other than to say that I think what we are beginning to see is that most of these trends and changes are basically beyond the historic range of variability, at least over the last 10,000 years for many species.

So there's this underlying question of what is the ecological response to these changes. And I would say that I tend to think about this in four different dimensions. One of them obviously is phenology. The fact is that when we're seeing changes in climate we might be seeing shifts in time or the life history patterns of many species, and because of that these phenological responses are obviously critical to document. At the same time we know that species are more or less distributed over geographic space, and we also know that climate has a very important role in basically constraining those distributions. And so how are those distributions changing in response to this warming? At the same time in terms of when we think about the mechanisms of this we think about shifts in demography, and that these demographic vital rates may play a very important role in influencing population dynamics at broad spatial scales. And ultimately that these can influence biotic interactions and how communities may be shifting over time in response to anthropogenic climate change.

So I'm really only going to focus on about three of these. I'm going to leave Amy to talk or present her wonderful work in terms of phenological changes in response to climate change. I'm going to focus primarily on distributions, dynamics, and biotic interactions, and show some of our current work in that. And I'm also going to start off talking about distributions and how those may lead to shifting communities.

So ultimately I think one of the most widely touted lines of evidence that species are in fact responding to modern climate change is this idea of poleward shift. And the idea here is that if we have a northern hemisphere that is warming over time, and the fact that the northern range boundary of let's say a southerly distributed species, theoretically in this example is constrained by climate. And as that climate changes we would expect to see a shift, poleward shift, in the distribution of that species over time. And this is really one of the most, even going back to the mid and late 90s, really one of the first tell-tale signs that species might be responding in a predictable manner to overall to climate change. And what I think we can say now with some measure of confidence is that this pattern seems to be relatively robust. And there's a review by Chen and there are other meta-analyses as well that basically suggests when we look at latitudinal shifts in species distributions across birds, across insects, across mammals, that this shift is in fact occurring in the direction that we would predict it to be. So Chen's analysis really looks at what we see in terms of empirical support of observed latitudinal shifts in relationship to what we expect if they are in fact basically following that climate space. And that shift seems to be fairly robust and resulting in this northward shift of species across sort of taxonomic groups of about 16.9 km per decade.

So there's this … So the line of evidence suggests that more than half of the observed animal range boundaries have already shown this response to anthropogenic warming. But what I would say underneath that poleward shift is that many species are showing very idiosyncratic responses; that some species are shifting northward as predicted, some species are doing it at very different rates, some of them are not shifting. And so there is this underlying question that I and many others have is that if we have all these individual species that are changing their distributions over time in relationship to climate, then what is impact on the community or the composition of communities?

And so one group of species I spend a lot of time thinking about are wintering birds, primarily because I've always thought about these as sentinels of climate change. They're persisting as many cold-adapted species are for a time of very rigorous conditions. They're constrained or sensitive to climate variability in terms of their use of resources, but also in terms of their distributions and potentially metabolic constraints. So looking at this group of species we pose this hypothesis that if there are shifting ranges of individual species that these ranges and range shifts should result in a re-shuffling of communities.

So how do we go about measuring this? Well the idea would be that if you were able to go out and look outside your window during winter you might see one community of species in the southeast, and this community of species as you go up the latitudinal gradient may actually change if you're in the mid-Atlantic region. And maybe you get some novel species, maybe a couple of species are dropping out. Maybe there's some slight changes in abundance of certain species, and as you get to the upper Great Lakes you'll have another group of species. And this species and its shift in community composition sort of captures this component of how might this composition be changing over time and certainly in relationship to climate change.

And so the way we go about measuring this is something called the species thermal index, which is basically a functional index that measures the long-term temperature experienced by individual species over its range. I'm not going to get into too much detail, but basically what you're doing is you're taking mean climate data, in this case winter climate, you're combining it with data from some sort of observational dataset, in our case Christmas bird count data. And when you basically take this information then you can actually develop a species thermal index. And so for example what this might look like is for the white-breasted nuthatch, and this is let's say a northerly adapted, cold-adapted species, that this species would basically have a species thermal index (STI) of -6.77. So capturing it's a means for minimum temperature conditions, basically its thermal profile. What's useful about this is that if you've got another species here that's more of a southerly distributed species that this species may have obviously sort of a slightly higher STI. So apparently what you're actually capturing is this different thermal profile between two species, and it is something of a relative measure when you've got a community of species.

When you've got this community then you can develop what's called a community thermal index. So for a species assemblage it's basically just a balance between cold- and warm-temperature dwelling species. And again I'm not going to go too much into detail other than to say that basically what this is saying is that you're summing up all those species thermal indices, you're taking the average, you're just using a current data in one case, and in another case you can actually weight it by abundance to look at some finer scale variation geographically.

So we wanted to look using this community thermal index (CTI), how is this sort of index changing over time? And so we look at data at from Project FeederWatch. I'm a huge proponent of citizen-science data. In the case of FeederWatch we've got a program that started in 1990. It has been continuing very successfully over the last 22 years or so, and it has got data from about 15,000 participants of people watching, recording what birds are showing up in their backyard throughout the entire winter season. The advantage of this kind of dataset is that for each individual site then we can basically identify a community thermal index profile for that community of birds, and if in fact you get one bird showing up or two birds, or three, or some change in abundance of those birds, then you can document how that community thermal index is changing over time. So in this case we've got Carolina wren popping in, and potentially showing a slight increase in that CTI.

So what have we found? And this is looking throughout the entire scope of eastern North America, and here we've got CTI on the 'y' and on the 'x' we've got 1990-2012. And over time we've been seeing an increase in that CTI, basically suggesting that warm-adapted birds are increasing in their dominance throughout eastern North America at many of these sites. What we've found that was a little surprising is that there's a lot of latitudinal variation in this. We've got increasing CTI in the southerly regions, and it's actually attenuating as we get northern, which is a little counter what we predicted. What we thought was going to happen was that we were going to have higher CTI in the more northerly regions, primarily because that's where we see a lot of the action occurring in the climate data. But that's not what we found. Most of the increases in CTI were occurring in the more southerly parts of the eastern US.

We can also identify which species are driving this. So we do this type of jackknife analysis where we remove species iterably and recalculate this relationship. And just to kind of give you some of the take-homes here what we find is to answer this question what species are really showing or driving this change in community composition; they are smaller bodied species that are southerly distributed and increasing their distribution. So most of what we see are species that are driving this trend in CTI, this community, this pattern of increasing dominance of warm-adapted species tend to be smaller bodied species that are presumably more sensitive to climate variability, southerly distributed, and increasing in their occupancy.

Okay. I'm going to take a quick shift here then, talking from distributions and biotic interactions now to dynamics and shifts in demography. And part of the reason I really want to talk about this is the idea of climate change vulnerability. And when we talk about vulnerability I think there are two main impacts or components that we try to assess and evaluate. One of them is this idea of sensitivity. So this primarily captures this idea that all species have vital rates that are more or less sensitive to climate variability, and so we talk about survival rates or we talk about reproduction. And so when we talk about wildlife there really needs to be a better sense of which of these vital rates are more or less sensitive to climate variability. At the same time is this component of exposure, and when we think about this geographically different populations are more or less exposed to historic and future climate variability. So the idea is if we can take some sort of mechanism or modeling framework where we can use demographic components as well as look at this over broad spatial scales and geographic variation we can have a better sense of trying to evaluate that vulnerability and over time try to gauge those conservation efforts that both incorporate this idea of which demographic rates are most sensitive to climate variability, and which populations are most exposed to historic and future climate variability. So the one example I'm going to point out, we've got a project where we're looking at multiple species to do this. But I'm just going to show you one example here, which is for ruffed grouse. So this is a cold-adapted species, who really shows a very interesting population characteristic that is demographically driven, which is population cycling. A number of cold-adapted species show these cycling events, snowshoe hare, lynx, and others where you've got in this case a northern Minnesota wetlands' populations of ruffed grouse that cycle very strongly, and as you go down in latitude, and this is a very common pattern, you see this attenuating impact of cycling where they don't cycle quite as much in southerly regions. So here we've got potentially a species that's showing weaker cycling in the south of its regions, and stronger cycling in the north. And some really interesting work is beginning to kind of surface right now suggesting that a lot of these sort of classical population cycles that we know in ecology tend to be strongly driven by climate. And not only that, but that many of these cycles potentially throughout the world are actually beginning to dampen over time, and part of that dampening in their cycling may have a very strong climate link.

So first that component of sensitivity. One of the first things we try to do is try to look at what has been collected empirically from studies in terms of adults and juvenile survival and nest success. So Lars is really leading the way on this kind of work. Basically he's able to collect information from roughly about 17 studies where we've got data on survival and fecundity, and then associate that with climate variability.

Once we do that then what we're trying to basically estimate is this demographic niche space, so what we can imagine here is that those sort of, those green areas are areas where we expect sort of low expected survival. So ruffed grouse are, require these snow roots, it has a very important effect on their over-winter survival. And so what you can imagine in terms of both precipitation and temperature throughout the winter season is that sort of warm, rainy conditions are not great for sustaining these snow roots, and their ability to survive both predators and inclement climate. And sort of cold conditions are also not great because you've got low snow potential, what you're really trying to get is that diagonal there, that cold high snow and warm low snow conditions, and that's really trying to get that sort of sweet spot of survival for this species.

When we look at the survival data, and this is kind of, I'm not going to get into the details of this too much, but this is basically again a projection where we're looking at nonbreeding survival and it's very strongly influenced by minimum temperature and minimum precipitation, and we're able to parameterize this basically using all of those black dots, which is basically those 17 studies there. And what you can kind of see there a little bit is that that milder winter temperatures and basically that precipitation, which is generally associated with rain, is that sort of upper right hand corner there, which we basically is that low survival. So you want to stay out of that, those green areas, which is kind of that death valley. We can take that information then and incorporate it into demographic model, and we can look at this variability geographically now over time. And what I can kind of show you here is about 30 years of that model of survival rate, and that's nonbreeding survival through the winter, and you can see how much that oscillates in these three different regions throughout the upper Midwest.

We can do the same thing for fecundity, nest success, and you can see about 70% of that variation is explained by temperature and precipitation. It's almost a little bit more unimodal. Basically you want to stay away from those extremes of summer temperature, both either too cold or too hot for the species, and it's an anomaly, that's why it's centered on zero. But I just wanted you to focus just on this idea that oscillatory behavior is much more reduced that nest success. There's a lot less variability. Much of it seems to be driven primarily by survival.

So that is that component of sensitivity. We're able to look at vital rates. We're able to look at see how those vital rates are potentially influenced by climate variability, in this case winter precipitation, summer precipitation, and temperature. And once we incorporate that what we can do then is now look at that exposure component by incorporating it into spatially-explicit demographic models, and we can have time series basically projections of populations over time. The real advantage to this is that we can use this data and make it spatially explicit, and then compare then to monitoring data. So here we've got ruffed grouse spring drumming surveys from over 300 survey routes throughout Minnesota, Michigan, and Wisconsin, and so we compare our model output to these monitoring data. And what you see there those colored lines are basically the outputs from our models, and then the dotted lines are the outputs from the monitoring data, and I'd say that we have pretty strong concordance, and really what it captures and one of the strongest components is that even though our models are almost primarily driven sort of loosely by land cover, but also by primarily dynamic climate variability that just sort of doing that alone captures this oscillatory behavior, especially in the north where we see stronger cycling and then sort of dampened oscillations in the south.

The nice thing about this in terms of trying to get to that exposure then is we can model our future variability in any cycling dynamics using some of the future forecast data. And that's really advantageous, primarily because what we're beginning to see here is that a lot of that variability in population cycling is not going to go away, but potentially is going to become more stochastic over time. And that potentially represents a problem because if you have areas or populations are highly synchronized, showing more variability in that sort of up and down cycling, you could potentially have these more likelihood of sort of localized extirpation events. So here just showing one year in those sort of upper regions of Minnesota there you can see basically those pink areas being sort of higher likelihood of population extirpation. And so that's probably one of the more sort of salient points I'd like to make is that population dynamics are driven by climate variability, and potentially with something like cycling are only going to become more intense and more variable over time.

So with that I'll kind of leave you with a few sort of take-home notes. One is that poleward shifts are definitely something that we're seeing really throughout the world and for multiple species and taxa. We believe we're showing some evidence here in reshuffling of species and communities, especially for wintering birds. But honestly there's been really interesting evidence on predator communities as well. That when we think about vulnerability of species I think we have to really consider this idea of sensitivity and exposure. We understand and appreciate that weather, climate influences vital rates, and so trying to get a better sense of which vital rates and which demographic parameters are most sensitive to this variation is critical. And I'd say we have to feed that into the assessment of exposure. Different populations are going to be more or less exposed not only historically in terms of their adaptive capacity, but also in terms of their future conditions and future climate variability. And ultimately this influences population dynamics, and in my case I was showing this example of cycling, but I think other population dynamics stand out as well. That when we have increased variability in the climate system, potentially many of these components such as population cycling are also going to be influenced and could lead to higher extinction risk. And with that I'd be happy to turn it over to Amy.

Great! Thank you Dr. Zuckerberg. I will… Let me get Amy's presentation up. Amy, I think you are unmuted. I'd like to introduce Dr. Amy Iler from the University of Maryland and the Rocky Mountain Biological Laboratory who will present 'Climate Change Effects on Broad-Tailed Hummingbirds'. Amy, I think you're all set.

Great! Thank you, Jill, and thank you Ben for that very interesting presentation. Again, thanks for the invitation to be here. I'm excited to tell you today about, I'm going to focus on a case study about how climate change is effecting the timing of hummingbird migrations relative to their floral resources. And so as Ben already mentioned and covered really well we're seeing two really prominent biological responses to climate change, including range shift, species moving towards the poles, and shifts in phenology. And today I'll be talking shifts about phenology. And just to make sure we're all on the same page, just very briefly phenology is the timing of life history events ranging from when trees leaf out in the spring, when animals go into or out of hibernation, the timing of migration, and also when organisms reproduce, which I'm showing here as flowering. And why we care about phenology very broadly speaking is that it very hugely determines the survival and reproductive success of organisms. So to give you an example with flowering, if a plant species flowers too early in a temperate habitat it risks being exposed to harsh abiotic conditions and that could lead to, for example, frost damage. So one kind of counter intuitive effect of climate change that we're seeing especially in the mountains is increased frost damage to developing flower buds, and that's because these plants are flowering earlier, and now they're flowering at a time when nighttime temperatures still get pretty cold, and colder than what they've historically experienced. And this kind of decreased floral abundance as a result of frost damage has implications for wildlife that depend on plants for flowers and for food, so like ground squirrels, marmots, deer, and in this case today that which I'll be talking about, hummingbirds.

And we know that phenology is by and large becoming earlier in many organisms. So the figure I'm showing you here is from meta-analysis. It was published a few years ago and it's on taxa across the United Kingdom. So you see first of all these negative bars that indicate earlier phenological events. And then the other thing I want you to notice about this graph then is that the phenological shifts differ among groups of organisms. So we see plants advancing at a faster rate on average than invertebrates. And those in turn advancing at a faster rate than vertebrates. So what this points to then is the possibility or what we call phenological mismatch, and that's organisms at different trophic levels that depend on one another maybe becoming mistimed. And I'm going to show some figures today that look more like this line graph on the right, so you see the day of appearance versus year, and that's now changed through time just basically converted to a regression style approach. So we see the steepest amount of change in the plants, relative to the other groups of organisms. And so we see this widespread evidence across a very broad geographic area for different rates of change in organisms. But if you really want to address this we need to have data on organisms that we know interact at the same location.

And so I'll be talking about that today from one location in the Rocky Mountains, and in the Tucson Mountain ranges. But before I get to that, I want to mention why might these organisms change their phenology at different rates, and that's because they depend on different environmental cues for different life history events. So two big ones as Ben alluded to are temperature and precipitation. And that precipitation can fall as rainfall or snowmelt depending on the season. And of course these are two abiotic factors that we're seeing changing very rapidly not only on average, but increasing variability. So that could be also contributing to this potential for phenological mismatch in different organisms.

And today I'll be focusing, as Jill mentioned, on the broad-tailed hummingbird, and if you want to find a paper, this work was published in *Ecology* in 2012 in volume number 93. And so this is a male broad-tailed hummingbird feeding on a flower. And this is the range of the broad tailed hummingbird. It shows here there are two subspecies. In the purple here is a subspecies that doesn't migrate, but today we'll be focusing on the broad-tailed hummingbird populations that do migrate. So they overwinter in Mexico, and then they spend their summers anywhere from southern Mexico up through the northern US in the west. And so what's interesting when we think about the phenology of a migratory animal is that they have to integrate cues along their entire migration route, and for birds a lot of birds use photoperiod or day length as a cue for when they leave their overwintering grounds. And in the case of the hummingbird then they're highly dependent on flowers for nectar, so when they're making that migration up to the yellow area in the map that I'm showing here on the slide they're going to have to track the nectar resources available to them. And one big thing we're seeing is that phenological shifts are bigger at higher latitudes. So we expect to see the see the change in flowering advancing at a faster rate at more northern latitudes compared to more southern latitudes. You might expect a scenario where the hummingbird is being held up on its migratory pathway because of the different rates of change and their timing of flowering for their food resources.

And so that's the main question that we're going to focus on is that are broad-tailed hummingbirds (BTH) mismatched with their floral food resources at the northern limit of their summer breeding ranges.

And so we've got data from two sites as I mentioned in the Rocky Mountains in Gothic, Colorado, which is where I am currently. And then also in Tucson, Arizona near the southern part of their breeding range, at least in the United States. And so in AZ the first nectar resource available to them is Indian

Paintbrush, shown as the red flowers here. And then in CO the first two species available to them are the glacier lily and larkspur. And we, I'm always having these great datasets due to these amazing natural historians shown here. Dave Bertelsen collected data in AZ. My post-doc advisor is David Inouye who has been following flowering in Gothic, CO for the past 40 years. And Billy Barr who also lives in Gothic has been tracking the hummingbird migration. So that's where our data comes from.

And before I show you how the phenology is used by organisms is changing I just briefly want to mention a little bit about how the climate is changing in these two areas. And this is what the AZ sites look like here. And then our precipitation. This is precipitation anomalies, so I'll walk you through this slide. In the green bars are the first of the earliest parts of the dataset, in the 80s to the early 90s. We see wetter than average across all seasons, so starting from Oct through Sept. And then in the middle part of the range in the mid-90s we see some variation. And then what I really want to point out is the most recent years we see drier than average conditions, especially in the fall and in the early spring.

And this is what the field site looks like in CO. And we have temperature and snowmelt information, so the graph on the left shows the temperatures are increasing in the summer. And when the snowmelts in the spring is also becoming earlier. And up here in the mountains this is the really important phenological cue, and we see that over the past 40 years or so the timing of snowmelt has been advancing by about three and half days every decade.

And so how do all of these changes in climate effect our flowers and our hummingbirds. Here is a picture from our, this is where I'm currently living and I just like to point out if you're not familiar with mountain ecosystems, snowmelt is a hugely important ecological factor. It provides a huge amount of water into the system in the spring, and obviously things can't get going in the spring until all of that snow melts, especially for flowering plants.

So first we'll move, we'll follow the pathway of the hummingbird in AZ. What we see here is the day of appearance of the hummingbird shown in red and the Indian paintbrush flowers shown in pink. Note neither one of those are changing through time. So we just see a bunch of scatter, and then if we subtract the timing of arrival and relative to the timing of onset of flowering, again there's no change at all. The hummingbird is arriving more or less the same time, which is when the flowers are beginning to flower. So in AZ things are timing up well.

Now if we look at CO we see a slightly different picture. Here's the first species to flower shown in yellow, the *Erythronium* is the glacier lily. And the hummingbird again is in red. And we see that the glacier lily is flowering about 5.5 days earlier every decade relative to the hummingbird, who is arriving only about 1.5 days earlier every decade. And what that means then is that there's fewer days between hummingbird arrival and flowering onset. And I'll show you a similar picture for the larkspur, the purple flower. Again we see the flowering is advancing at a faster rate than the hummingbird migration is advancing, meaning there's fewer days between hummingbird arrival and onset of flowering. And your first question might be, isn't that a good thing? There's fewer days between when hummingbirds arrive and when the flowers begin, and that is a very legitimate question. However, what we see in these hummingbirds is that the first individuals to arrive in the spring are the males, and they're extremely territorial so they want to arrive and set up their breeding territory early and historically that has occured about two weeks before flowering starts. And now we're seeing the males are arriving with much less time to set up their territory, and we think what could be happening then is that might be squeezing our time frame of reproduction into a smaller window.

So putting this back all together then. Of course our original hypothesis is that hummingbirds are being mistimed with floral resources at the northern site, but not at the southern site. And we expected convergence in phenology to continue for some time given that we're seeing these pretty fast rates of change in flowering species without any evidence of slowing down yet. And we think as I mentioned this late arrival is probably going to shorten their time frame for reproduction. And we're trying to follow up on this by following hummingbird nests. So we have some historic data that we can follow, we can compare to, and we know that historically the females start to breed when the first larkspur flowers arrive. And now we're seeing some years where that's when the males only arriving a few days before those larkspurs begin to flower, so that would suggest that the females also are kind of following behind schedule. But that remains to be seen.

And before when I wrap it up then we know a little bit about changes in phenology of other wildlife at this site in particular. So the hummingbirds aren't the only species that are showing some very slight changes in their arrival times. The American robin pictured here on the right, we see a very slight change in its date of first sighting. So it's becoming earlier, but not at a hugely fast rate. It's actually pretty similar to the hummingbird. And in terms of when the marmots come out of hibernation, that's also becoming earlier. And what we ultimately would like to do is link these changes in phenology to some type of demographic consequence like Ben was showing. And for the marmots there was a great study that came out a few years ago doing just that, showing that this earlier arrival or earlier emergence from hibernation in the spring is leading to the marmots being active for a longer growing season. So they basically have a longer summer in which to eat and fatten up for the winter, and they saw a very big population increase because of this fact. So for the marmots they're actually doing better under the climate change scenario.

And with that, I think that finishes up the phenology section, and I think Ben and I are both happy to take any questions from the audience.

Okay, thank you Amy! That was great! We've gotten a lot of questions, so let me just get started here and we have Ben unmuted, so and what I'll think I'll try to do is since I think there's several questions that probably both of you will either want to or can answer, I'll pose it out to first Ben and then Amy if you want to add anything more. If there's specific ones for you Amy that I'll directly ask you, if that works for both of you.

Works fine for me.

Yeah! Sounds great.

We have had several questions dealing with plant communities and animals, so let me ask you one specific question was have we seen similar poleward shifts in the plant communities associated with these animals, and are there plants that these birds rely on that would affect their ecological impacts? I think this might be more, I think this was directly for, from Ben's presentation, but I'm sure Amy you can add to it.

So let's see, as an avian ecologist I'm always a little hesitate to throw too much sway behind what I saw about plant communities, but I do think that yes, I think there has been pretty strong evidence. I think there's a temporal scale obviously a little bit different, and I think a lot of these meta-analyses and these kind of original meta-analyses were a few years ago I want to say that looked at fingerprints or footprints of climate change. And these poleward shifts are definitely one of them. And I think a lot of those studies came from Europe primarily. I'm looking at poleward shifts in plant communities. I know that in some modeling frameworks there's been a lot of interesting sort of distribution models that try to look at how plant communities will change over time just in terms of modeling niche space. And most of that is seeing sort of this sort of more, at least in the upper Midwest region, sort of more shifts to northern hardwoods and sort of a degradation of more conifer-adapted communities. But Amy I'm happy, you know, see what you think about that.

Yeah, I totally agree. I think you answered it very well, especially pointing to the temporal difference and what Ben means then of course is that plants aren't quite as mobile, so they have to disperse their seeds, and then have germination to have new populations. And I think that there is some information suggesting that this just happens indeed as you would expect at a slower rate than with animals. And I think a really interesting question then is what that means for the animal communities. How do they switch to new resources? Are they limited by their plants? You know, we don't really know a lot about that I don't think.

Okay, great. Thank You. Amy, this is a question directed towards, for you from a middle school class. Why do you think you aren't seeing similar hummingbird data in AZ that you are in CO?

Good question. And that's actually the pattern we saw was what we expected to see. And we think it's because we're not seeing as rapid of changes in the flowering times in AZ, and actually some of those plant species are even showing delayed flowering because of the droughts that are being experienced in that region. So the droughts are leading to delayed flowering, which is kind of the opposite of what we're used to hearing about climate change and flowering. And so that's one reason that we're seeing a different thing happening in AZ than in CO.

Thank you. I have another question, and I think it was during, Ben, your presentation. A question dealing with Chen's study. People were wondering if that was global or if that was solely in the US?

I believe that was global.

Okay. Another question is dealing with the CTI, and thank you for everyone who clarified what CTI, community temperature index, was. I didn't know what it was. Here's the question: could the reduction of the CTI as you go northward be a lag related to a slower vegetation change?

Huh… that's a good question. It, I would probably say probably not in that I would say most of the species that we were looking at are species that are considered to be somewhat generalists in that they can take advantage of very different kind of cover types or plant communities. All these species are kind of more or less at least able to survive in human sort of adapated or human-modified landscapes, like suburban areas, and even some urban areas. So I would probably say that it's probably not plant communities, but what I would say is that, and I think we're still trying to get a sense of this, is that some birds if you kind of sort of map their, where they like to be in terms of their climate space, and then see how that climate space has moved over time, and then see how well some of these wintering birds can actually track that climate space. There's some really neat work by a guy name Frank La Sorte that's basically shown that sometimes it takes them anywhere, they can practically track it from one winter to another, but some years it takes them 30 years to shift along with that climate space. So even species that we think about with, like birds that can fly and they're very mobile, even sometimes it takes them a long time in order to track that climate space.

Great. Thank you. A few questions dealing with hummingbirds. One question is does the data from the hummingbird, and I think its marmot, sorry I'm not a bird person, and robin from 2000-present day follow the trend in phenology shift?

Um… I'm not sure I quite understand. So does it follow the global trend, or…? So yeah, those trends that we're seeing in terms of earlier emergence of marmots, slightly earlier arrival of the birds. Okay I can answer that in two ways. The marmots and the flowers, for example, those are fairly similar to kind of global averages. The birds, these two species in particular are maybe a little bit slower to change relative to the average. I think it's more around 3 days per decade earlier, and these are more like 1 day or 1.5 days/decade. And so the hummingbird, as I explained, we think that might be because their floral resources could be holding them up, at least through time. And for the robin it could be a similar thing if they rely on spring break, and you know when the worms and caterpillars and the things that they eat become available.

Great, thank you, Amy. Another question dealing with, that was within your presentation, Amy. We're seeing frost damage in Michigan well away from mountains. Is increased frost damage a documented North American or global problem, or perhaps just a coincidence?

Oh, yes, good question. I did misspeak a little bit in that it is a documented phenomenon, certainly across North America. I know in MI they lost a lot of their cherry crops. And so this is a phenomenon that is affecting not only natural plant communities, but also some crop species, like apricots, cherries, things that flower early in the season in the spring are all experiencing this problem. So it's a fairly widespread phenomenon, and in Europe it's happening as well.

Thank you. Ben, a couple questions for you. One question is can you discern changes in wildlife distribution with changes in land use? The latter which may also be driven by climate change.

That's a great question, and I think it's something that we're continuing to look at. So my feeling on this is that these two impacts of climate change and land use change are not working separately, that they tend to be synergistic. And one really good example that's another study that we recently wrapped up, and is coming out in *Global Change*, where we looked at very similar approach that kind of ruffed grouse, but with eastern Massassauga rattlesnake, which is a species that's declining significantly throughout its range. And what we're really kind of able to see is that when we tried to look at how climate variability influences the persistence of these populations of snakes throughout the upper Midwest, we can really do a much better job when we incorporate information on like agricultural development or on land cover. And in fact when we only looked at just climate variability alone, and then when we separately looked at only just land use change alone we didn't do a very good job. When we incorporate those two components that's when we were able to actually have fairly strong predictions of which populations are more or less at threat. So I would say that it's a really sort of an area that we're all trying to explore many different ways, and I think that's a really good example because in some cases when we talk about things like drought or when we talk about extreme flooding events, those can be the magnitude of those events can be very much influenced by the surrounding land use, whether it's agricultural or urban development. And so I think it's a good question. It's something that's a fairly, actually it's somewhat difficult to be able to tease apart. But we're doing our best with it.

Another question, Ben, for you. Do you have any, can you talk a little bit about population information on Great Lakes amphibians or reptiles?

Ooh, ouch.

Oh, is that beyond what you…

Yeah, I could probably, yeah…

I just wanted to make sure, and I thought so, but I just wanted to make sure.

Sure.

We will skip that.

Sounds good, haha.

Another question that we had was, and again this is for you, Ben, was dealing with, and I'm sorry now of course I have missed it. Why do you think the CTI has remained stagnant in the Great Lakes region? Has there been little change in community composition in this region? Or have warm-adapted immigrants been offset by extirpation or other warm-adapted species?

Yeah, it's a really good question, and it's something that honestly we didn't expect to find. We actually expected the CTI, the community thermal index, which is, you know, I was kind of talking about this balance of warm- and cold-adapted species, that we'd be seeing most of it occurring kind of in the Great Lakes region and in other parts of the northeast United States. What I would say a little bit is that potentially what we're, what I think is really driving this pattern and I think it's going to kind of begin to percolate up north as well is that a lot of this is driven by very sort of changes in abundance of southerly distributed species. And so most of it tends to be driven by colonization increasing species in terms of their distribution and abundance as opposed to let's say you know really cold-adapted species who are becoming extirpated or leaving. We don't see a lot of information, now not to say that that's not occurring, but what it really does seem to be driven by is this sort of colonization impact of southerly-adapted species, of warm-adapted species. So and I just at least in my thought about it a little bit is that what we do tend to sort of need or at least it seems like for some of these birds to kind of catch up to their climate space is actually a bit of a hiatus in warming. When you do have these sort of periods where the warming is kind of taken a long-term sort of break from its trend, and in the southeast that's actually been noticed to some extent. So we are kind of interested in whether or not eventually that sort of CTI change will eventually kind of percolate up to the north, which we expect it to.

Great. Thank you, Ben. A question that we had gotten for, Amy, this is for you. Are hummingbirds significant pollinators? And if so, how has the hummingbird population affected plant population in the CO area?

Yes. Hummingbirds are very important pollinators, especially of those two plant species I showed you. So the, those two species are pollinated primarily by hummingbirds and by queen bumblebees, which are really the only things out that are good pollinators early in the season for those plant species. And we don't have information on the success of those species or their population dynamics unfortunately. So it's hard to say for certain. I would say so far we're not seeing any huge signs pointing to declines, and I think one thing that we might see is very strong selection eventually against earlier flowering. If those individuals don't get pollinated and aren't' successful. So hopefully there's kind of a buffer built in, but that remains to be seen.

Okay, thank you. Another question, Amy, for you dealing with snow events and hummingbirds. If a significant snow event hits the hummingbirds when they're setting up territories they wake up with no food. Do they, do these early males die or can they retreat and come back later?

We are fairly confident that they males retreat, and we think they even they live in kind of temporarily set up camp down at lower elevations where there are some flowers, and then they make scouting trips during the day. And then once there are enough flowers at the higher elevation where they have those breeding territories, then they assume residence and they stay overnight. And they go into torpor when it gets really cold, and so they're kind of at a, their metabolism is reduced. They're pretty amazing little creatures and they can withstand pretty cold temperatures. And so the reason we think they do that is because we don't see them very early in the morning or very late in the day until there are flowers here on site. Otherwise we concur they're making little scouting trips. But great question.

Another question that we had was dealing with habitat management implications for, really for both of your research. Could you talk a little bit about what maybe some of those habitat management implications are with respect to wildlife species, and is monitoring the most important aspect for now? Ben, I'll start with you, I guess.

Sure, yeah. I would say that a lot of our vulnerability assessment work has kind of focused both for ruffed grouse, but also for eastern massassauga rattlesnake. I think there's significant implications for habitat management, and primarily because for two very different reasons that I kind of mentioned before, and I kind of didn't show this work, but was rattlesnake work. You know, we really do kind of show that the amount of agricultural impact in an area surrounding area does in some ways exacerbate these climate effects. And so trying to get a sense of water table management in the case of the rattlesnake, but also how to limit land use change in these areas, or how to sort of basically buffer them from sort of climate extremes is really critical. For the ruffed grouse, I'd say too that, you know, part of this cycling phenomenon does have a component of that the cycling is decreased in areas like that are fragmented by forest or forest fragmentation, and so trying to have a better sense of, you know, when we do see these climate conditions or how climate mediates some of these sort of demographic consequences. I'm trying to understand how it works interactively with forest fragmentation in that case or even with a forest maturation processes. It's something that I think really has strong habitat management implications.

Yeah, and in terms of the hummingbirds and their phenology this is only one population, and you would love to have more information on multiple populations, and that is monitoring becomes hugely important. And I really can't underestimate how important ecological monitoring is. It's been great with a lot of more investment in citizen science, it has been great especially in terms of phenology. We've able to get more information, but if you ask it's fairly tricky to make a habitat management recommendation based on one population at this point. So I would, yeah, I would emphasize monitoring right now at least for this species in particular.

Yeah, and sorry I'll also double down on that monitoring aspect, too, that none of this would be possible I think without long-term monitoring data, both in terms of being able to kind of validate some of the models, but also for citizen science data if those people weren't out there collecting this data they have been for the past 20 years we'd really have nothing to say.

Okay, thank you. We had a few more questions dealing with hummingbirds and research that is going on about what could happen to hummingbirds in the Great Lakes region. There were a couple people from like the MI area that were asking about their hummingbird species, and I don't know, Amy, if you would be able to comment on any of research going on specifically in the Great Lakes region.

I honestly don't know about the hummingbirds in that region. Yeah, I think there's probably some opportunity to use some of the eBird data to get at some of those questions, but I'm not aware of any present studies.

Okay, okay.

I think those are the majority of the questions that we have. I'm sorry, I'm trying to kind of go through and make sure that I'm not missing a key question. But I think actually that is the majority of the questions. We really appreciate both of you answering all these questions. We had 20 minutes questions and answers. That was great! We really appreciate that.

Well, so I would like to actually close and we will conclude this webinar. I want to again thank Dr. Zuckerberg and Dr. Iler for their willingness to talk to us about their work. It was really an excellent discussion. Also, a thank-you to Ohio State University, the National Sea Grant College Program, and

Ohio Supercomputer for funding this webinar. I did want to remind you that our survey url for this webinar is in the 'chat' feature, so please feel free to take a few minutes to fill that out. I also wanted to refer you to resources and an archive of all previous webinar presentations, which are located on our changingclimate.osu.edu website as well as our new regional site at greatlakesclimate.com. This webinar series is sponsored by the OSU Climate Change Outreach Team and we'll continue next month with scientists from Ohio State University who will be discussing farming, urban development, and climate change in Lake Erie. The registration is up in the 'chat'. Thank you again to Ben and Amy, and all the participants on this webinar. We hope that this was beneficial, and hope you'll join us again in an upcoming webinar. Thank you again, Ben and Amy! That was a great presentation, and everyone have a great afternoon. Thank you.

Thank you!