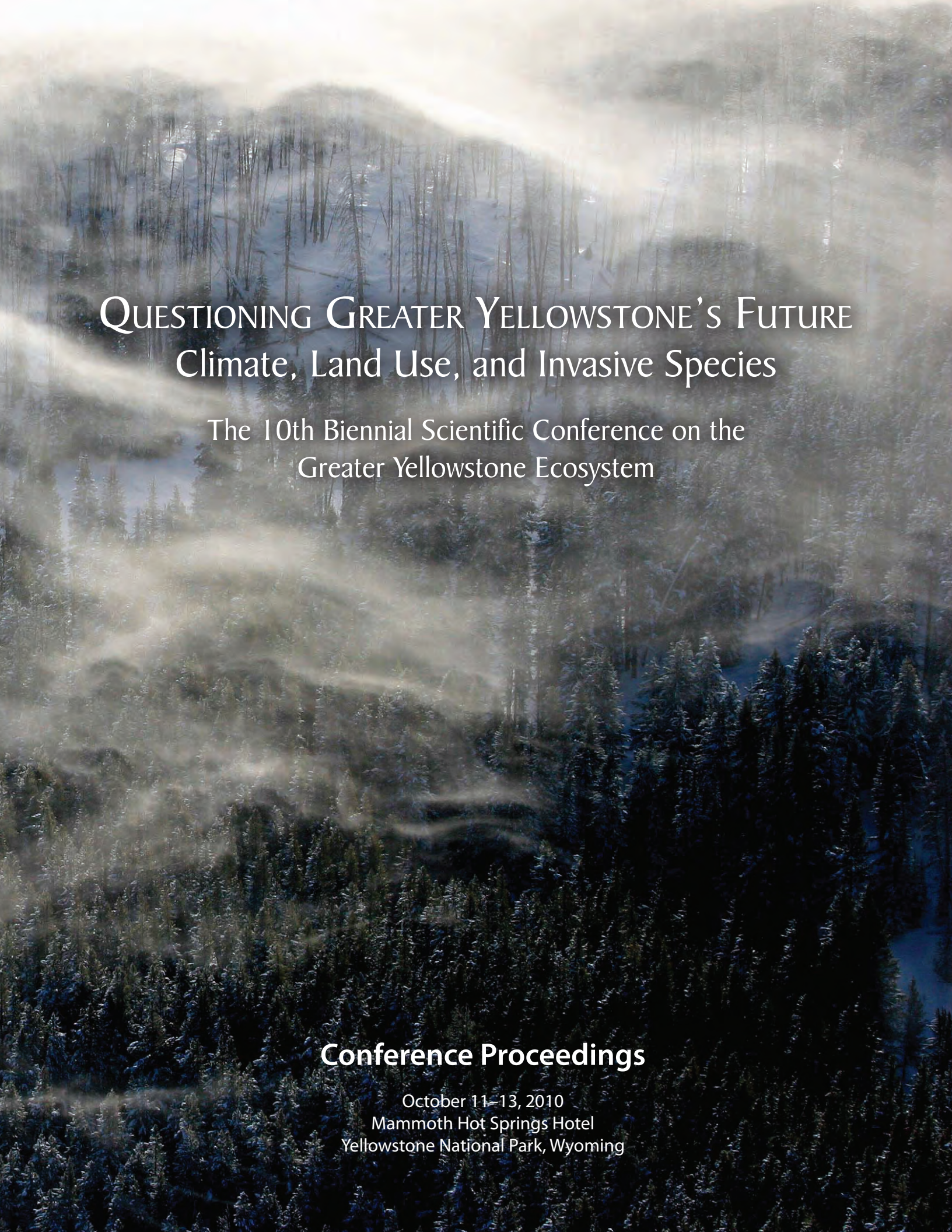

Questioning Greater Yellowstone's Future
Climate, Land Use, and Invasive Species

The 10th Biennial Scientific Conference on the
Greater Yellowstone Ecosystem

Conference Proceedings

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Mammoth Hot Springs Hotel
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Keynote

Land-Use Change in the Greater Yellowstone Ecosystem: Past, Present, and Possible Future Patterns and Consequences

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Note: The text that follows is an edited transcription of the speaker's remarks at the conference.

Introduced by John Varley

Good afternoon, folks. I wonder if we could start by thanking the folks that put this all together. This conference has been just great…particularly the planning committee of Tami [Blackford] and Emily [Yost] and Janine [Waller] and Mary Ann [Franke]. Great job.

The program committee is varied. They selected a really good group of folks…lots of interesting topics. I'd like to thank all of you…yesterday I was sitting in the audience and thinking that this is one of the most special meetings that I ever get to attend. What is it about these meetings that I like so much? Well, they're all about Yellowstone and it's always good science, but the main attraction is that we all feel like we're part of a community, part of a research management community that is based on this place, and that's a really special thing.

I've noticed that over the years that there's kind of a turnover in who is doing the work in Yellowstone, and I don't know if it's a five-year longevity or eight-year, or whatever, but it's really critical for a new wave of people to be coming in and picking up these really important studies and continuing the work. So, it's always fun for me to see the new folks that are at these meetings…I really appreciate it.

And finally, it's really important to highlight the incredible quality of the science and the outreach that has come out of the YCR [Yellowstone Center for Resources]…at least for 20 years. And many have said that it was true for years before that as well. That doesn't just happen, you know. It happens because there are very good people working hard to make it happen and so, among others it's John Varley, and it's Tom Olliff, and it's Glenn Plumb, and it's Don Despain, and Roy Renkin, and it's Doug Smith, and P.J. White, and so forth…it's anything but guaranteed that that will continue in the future. You don't get really great programs that just continue without a whole lot of work. So, I'm just hoping that we'll all help to emphasize the real benefits of trying to ensure that we have this super high quality program here in the park in the future. So, anyway, I'd just like to thank all of you for what you've done for all of us and the park over the last several decades. So, again can we give them a round of applause?

Okay, let's look at some of the history of the area and bring it up to the present and take it up to the future. I'd like to speak to why Yellowstone is so special and how we might try to sustain it into the future given its very special qualities. I think we all know that it is fairly unique in the Lower 48 in terms of being an area that was the latest to have Euro-American settlement and the earliest to have a national park. And, of course, it continues to have that wilderness character, but in addition to climate change there is also a big influx of new residents and substantial land-use intensification.

So the topics that I will talk about today are these:

- Looking at the period of change in human populations and land use from about 1860 to present and projected into the future. Why does this matter ecologically and how might land-use change influence changes within the park? How does the land-use story compare to other parks around the country?
- I'd like to then talk a little bit about how the park and the state of the ecosystem here might influence the human communities in terms of economics, attitudes, and wellbeing.
- And then, finally, end with a few comments on how we might sustain this system.

Mike Huston wrote an interesting paper that basically put forth that Euro-American settlement in the U.S. was first driven by natural resource constraints. People needed to live where resources allowed them to…particularly agricultural lands. Then, once transportation allowed the movement of resources, people tended to move along transportation corridors. And, of consequence, right around 1870—the time Yellowstone was established—the distribution of population in the U.S. was heaviest along

the Eastern Seaboard and the Midwest and the good ag [agricultural] lands, and some communities starting to form on the West Coast. The whole intermountain area was fairly sparsely populated. And when we focus in on the area that was around what would become Yellowstone Park, notice that there were small settlements of Euro-Americans. For example, in the Gallatin Valley, but most of the area around the park, was either Native American reservation or these interstitial lands that were occupied by Native Americans that refused to go to the reservations.

To get here at the time, people had to travel on the Oregon Trail just west of us into Utah and Idaho and then backtrack into the Yellowstone area. Because this was a very long route, the Bozeman Trail was built in 1864 as a way of allowing access into this area from the east. It was only open for four years before it was closed under the Treaty of Laramie, and it remained closed until 1876… just after the Battle of Little Bighorn. The following year was the Nez Perce War. These two battles represented the last Native American resistance across North America, and it is notable that that happened right here in our system.

So, this area stayed wilderness and unsettled while most of the rest of the country had been well settled with permanent infrastructure for more than a hundred years. How did the human population size change in the years after that? Well, it grew fairly quickly in 1900–1920 as settlers came in, but then there was this many decade period of very slow growth up until the 1980s, and then growth rates increased…particularly in the last two decades. So, now we're at around 425,000 people in Greater Yellowstone.

If we look at density of rural homes (those outside the towns) starting in 1880, there were very few and the increase was very slow up until the 1970s. So, the rate of growth spikes in the '70s and then again in the '90s. There was a continued boom in Montana up to 2005, and the current recession probably accounts for the slight decrease in numbers of…in the growth rate of homes in this area [Figure 1].

So, what might explain that growth? This is a wilderness-type landscape, why did all of a sudden people start coming here? Well, Huston put forward that the third major driver of land use across the country was natural amenities. That, as of the 1980s and '90s, wealth increased, education levels increased, transportation opportunities increased, information transfer became easier through the Internet. Of course, people could move to where they used to have to live for their job to places where they really wanted to live, and a lot of people chose to live in wilderness-type settings—exactly the sort of place like Yellowstone that people avoided earlier due to all the reasons that I mentioned.

So, consequently, if we now look at the distribution of rural homes around the Greater Yellowstone Ecosystem… the parks, the light-green public lands, and then the gray are the private lands; blue represents the density of rural homes…and notice that rural homes pretty much ring the public lands, not only in places like the Gallatin Valley where there is a university, airport, etcetera, but even in some of these river valleys like the Woods River that are

Figure 1. Exurban development (center) and forest dieback (bottom left) in the Gallatin Valley of Montana, in the Greater Yellowstone Ecosystem. Photo by Andrew Hansen.

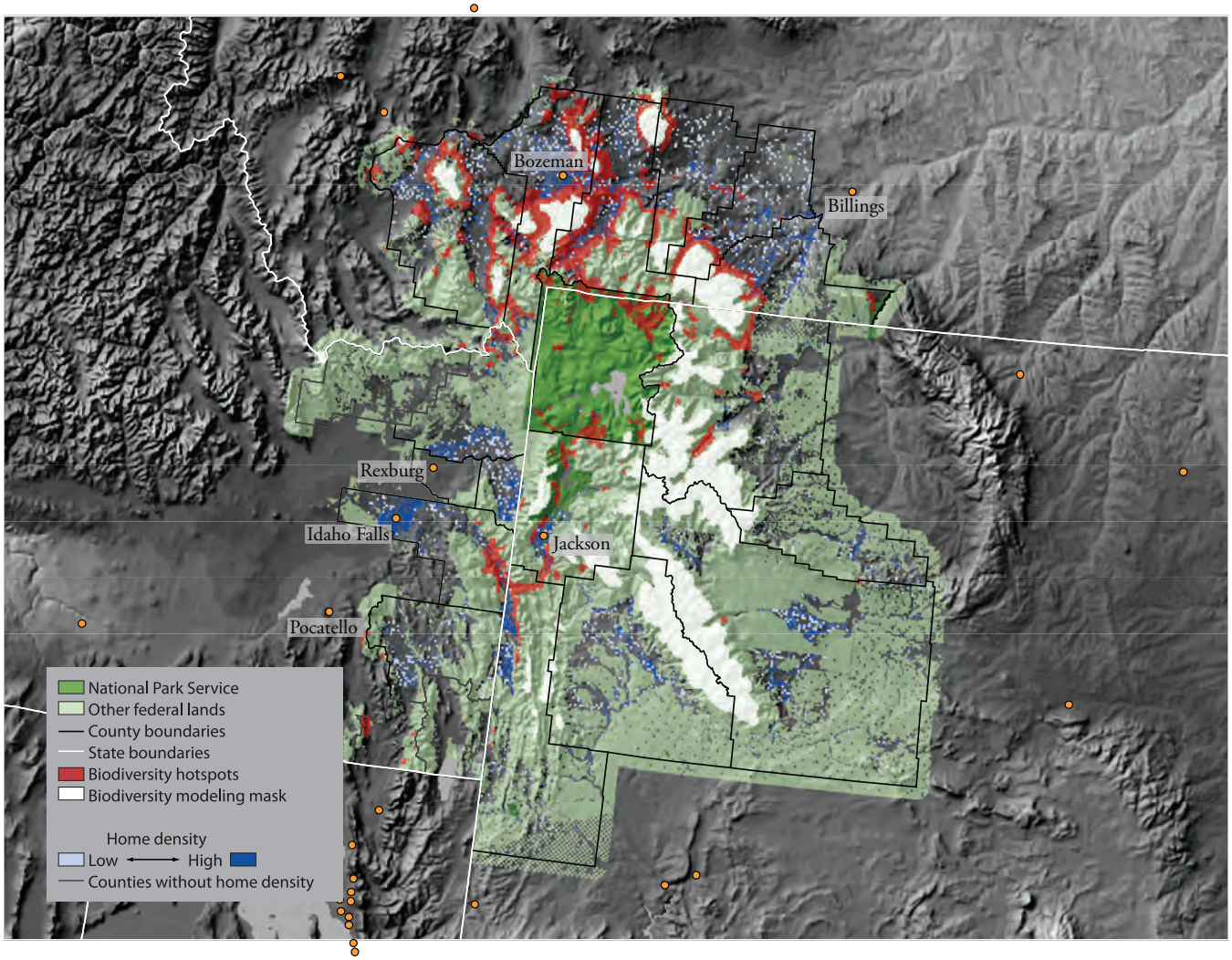

Figure 2. Distribution of rural homes across the 20 counties of the Greater Yellowstone Ecosystem in 1999.

a long ways from any town or airport [Figure 2]. A lot of these people are coming here for the natural amenities… that's what was determined by a study that Patty Gude, Ray Rasker, and I and others did. We did a statistical analysis of correlates with rural home growth and found that it was statistically associated with traditional things that Mike Huston hypothesized with agricultural suitability and with transportation factors and with past development, but also with natural amenities. It's a combination of all these that are contributing to this growth.

What about the future? Well, more of the same. Projected to 2040, the population under this particular one of the IPCC [Intergovernmental Panel on Climate Change] scenarios would go to 725,000 here…almost a doubling. Our projection of rural homes up to 2020 shows a mid-range scenario of almost a 100 percent increase in rural homes. So, we expect to see a fairly dramatic continuation of these patterns into the future.

Okay, so what does this matter from an ecological point of view? We did a general synthesis of how land-use change can affect ecosystems and biodiversity and identified these four groups of mechanisms related to [it]: habitat change, change in ecological processes, biotic interactions, and human disturbance. These can affect the population dynamics of individual species and, in turn, influence community structure and diversity.

Let's look at a few examples of these from our system. First, the habitat change. In the GYE [the Greater Yellowstone Ecosystem] 88 percent of land is public. That alone is important because we know you can't build houses on public land and so intense land use is less likely in those lands. So, we might think that the system is fine. Areas that are urban, or exurban, or suburban cover just 11 percent of the system at present.

How has that been changing over time? Well, the ag lands have been fairly stable over most of the century in

terms of their area and decreasing over the last couple of decades. The big increase has been in the area of exurban development and under urban and suburban development. But again, only 11 percent, so maybe we're okay. Those lands especially are far from Yellowstone and Grand Teton Park, so maybe [are] not a problem. Well, there's a couple of ways where there is potential for negative impacts…one of these being that it just so happens that we're building homes in areas that are disproportionately important ecologically. It's going to be low elevation, well watered, longer growing seasons, high primary productivity.

Bird hot spots, places of particular[ly] high numbers of bird species—which also coincide with high tree and shrub diversity—significantly overlap in places of rural homes. The homes are built just in the bird hot spots. So, the notion is that although much of the system is public and is not converted to intense land uses, that land that has is the most important land in the system ecologically. That's also true from a migration perspective, where many of the ungulates that migrate out of Yellowstone Park are passing through these areas that have rural home development.

If we look at a whole variety of indices of habitat ranging from individual species like pronghorn to habitat types like Douglas fir to what I like to call indices of habitat like bird hot spots or migration corridors or irreplaceable areas…the message here is that some of the habitat types that are largely in the public land, like pronghorn and moose, have undergone very little destruction as a result of this land-use development, but others that tend to be down in the valley bottoms like bird hot spots and riparian habitat have undergone almost a 20 percent decline as of 1999, and under the projections up to 2020 it will be more up to [a] 20–30 percent reduction. So, there are particular habitat types that are indeed getting substantially fragmented by this land use.

But, perhaps even more important are what we might call the "longer distance effects." The effects on the natural part of the landscape that might be some distance from the lands that have the more intensive land use. With regard to ecological processes, we know that natural disturbance is critical to the maintenance of ecosystem function and biodiversity in the system creating habitats that many species require like cottonwood and aspen and flooded riparian zones and early burn patches for things like woodpecker and (again) aspen. We know that the ability of land managers to allow disturbance to occur are dramatically constrained by the presence of these rural homes and so the notion of a "let burn" policy in Greater Yellowstone… maybe it might still be on the books, but I don't think it's happening anywhere. I mean, any fire that is threatening homes, we're trying to put out. There's also been a lot of controversy about the extent to which flooding might need to be controlled to protect homes. For example, like in the Paradise Valley.

One other ecological process that you might not think about being susceptible to land-use change is primary productivity and its spatial and temporal distribution across the landscape. Nate Piekielek, a student of mine, has recently been working in the Yellowstone watershed from about the Pelican-Hayden portion of the northern range down the valley to Livingston. We've broken it up into six sections and [are] looking at patterns of NDVI [Normalized Difference Vegetation Index]. Averaged for the last 10 years, the start of the growing season is generally earlier in the valley bottom [near Livingston]. As we long thought the case, the data are confirming that. For those months of March, April, May…there's substantially higher green vegetation in that portion of the study area.

But then, of course, there is a flip over in July, August, parts of September, where it's the upper portion of the northern range where the fast-growing green grass is found, and this is likely the really limiting time of year… having green forage in summer, which requires summer rains and is only happening up in the higher elevations where you have the summer rains. So, these patterns of chronology explain the migration patterns from winter range to summer range and back.

Well, is land use influencing this at all? So, Nate is now focusing on just the portion of the Paradise Valley below the public lands…Nate did a similar plot for undisturbed grasslands, but also for rural home density, suburban, urban, and areas of irrigated agriculture. He found that green-up in the spring is happening a lot earlier in the areas of intense land uses than on the natural [lands] and it's continuing later in the fall. And also, the irrigated agriculture over most of the growing season is way more highly productive than those natural grasslands.

We think that this likely explains the change in the spatial distribution of the elk, in particular, over the course of a year, with many more of them staying lower in the valley over parts of the summer and especially in the fall. Bigger implications of these higher densities and reduced migration in terms of spread of disease like brucellosis…and of course that spread to cattle. In terms of the location of predators like wolves, perhaps bringing wolves down into

more contact with domestic livestock and creating those kinds of problems and in reducing the ability of management agencies to use hunting as a tool to reduce herd size. A lot of these herds are just hanging out on private land where there's not good hunter access. So, this might be a good example of where land use pretty far down out of the park is probably having fairly strong impacts on migration and spatial distribution of ungulates, including the time they spend in the park, in ways that strongly influence policy.

Okay, let's move on to another example that involves biotic interactions. Now if we go from a wildland setting to an increasingly urbanized one through these land-use types, in general the literature suggests that you tend to get changes in types of species present with the reduction of top predators fairly early as the system leaves being a wildland. A variety of predator-sensitive natives tend to drop out and that's because a lot of mesocarnivores tend to be more abundant, like raccoon, skunk, magpie, raven, for example…as indicated by these human-adapted natives. And then, of course, weedy species tend to increase. This can have big consequences for the distribution of biodiversity across the landscape.

Just one example that goes back 10 years or so: we've looked at neotropical migrant bird population dynamics…in this case the yellow warbler. We found that hot spots that were near high densities of rural homes…within those there was much lower reproductive success for those birds than areas with lower home densities. And the main mechanism of that was the expansion of the mesocarnivore community like ravens and magpies. Also, cowbirds that of course lay their eggs in the nests of species like yellow warbler and have very dramatically reduced the reproductive success of yellow warbler and several other species.

When you project rates of reproduction and rates of survival across the landscape as a function of rural home densities and habitat types, you come up with some interesting things. We found that for American robin—a species that is not susceptible to these mesocarnivores or cowbirds—that these riparian, low-elevation areas are population source areas where there's lots of reproduction. The areas up in the park where their species are found have fairly low reproduction some years due to climate limitation, and so it appears to be a system where there are population source areas in the valley bottoms that are probably maintaining vital populations up in the park.

We think that in pre-settlement times that was likely the case for yellow warbler, too, and other neotropical migrants that are very sensitive to these mesocarnivores. But when we model the population growth currently under the current distribution of rural homes, we find that all of these hot spots are population sinks and there's mild sources in the foothills of the Gallatin National Forest, say, but the park is a mild sink due to climate limitation. And this suggests that the conversion of this area from source to sink has flipped the whole system over to a sink. It's an example of where land-use intensification, in this case 40–60 miles away from the park, could be affecting population viability within the park.

Now, I know that yellow warblers are high on your list of most important species, but allow me to divert attention to a less important species like the grizzly bear. Chuck Schwartz and his many colleagues have done really beautiful work asking similar questions for the bears across the system. Just to summarize, they find that mortality is the main driver of population growth for this species. They find that 85 percent of the mortality was human-caused in their study that summarized the last 20–30 years. The rates of survival were decent within the park, a little bit lower in the recovery area outside the park, and in the private lands outside the recovery area substantially lower. They found that these mortality rates were correlated with some natural things like winter severity, but also with several land-use factors, like stuff related to roads and home density. They then modeled population growth over the system…similar to what we did for birds. The maps they've put together are pretty alarming because on one hand, the population is growing overall right now and especially growing on the public lands, but it raises totally the question of: if we do get that doubling of population and of rural homes, at what point does the mortality in the private land for bears become sufficient to force the entire system to become a sink…and put at risk the species in the park?

If we simply overlay the projected 5 degree Celsius change in temperature over 100 years that David Westland just mentioned, which I found amazing, and effect on whitebark and fire, we can really expect that the bears are going to want to be on these lower-elevation lands. So, this is an example of where land use alone might have an effect on a charismatic species. Match that with climate change [and] some really serious challenges [emerge].

Okay, now let's move on to a comparison with other parks across the country. Cory Davis, another student in my lab, has been analyzing the 60 larger parks in the Lower 48 in terms of land-use change using a variety of metrics dealing with population density and housing density and

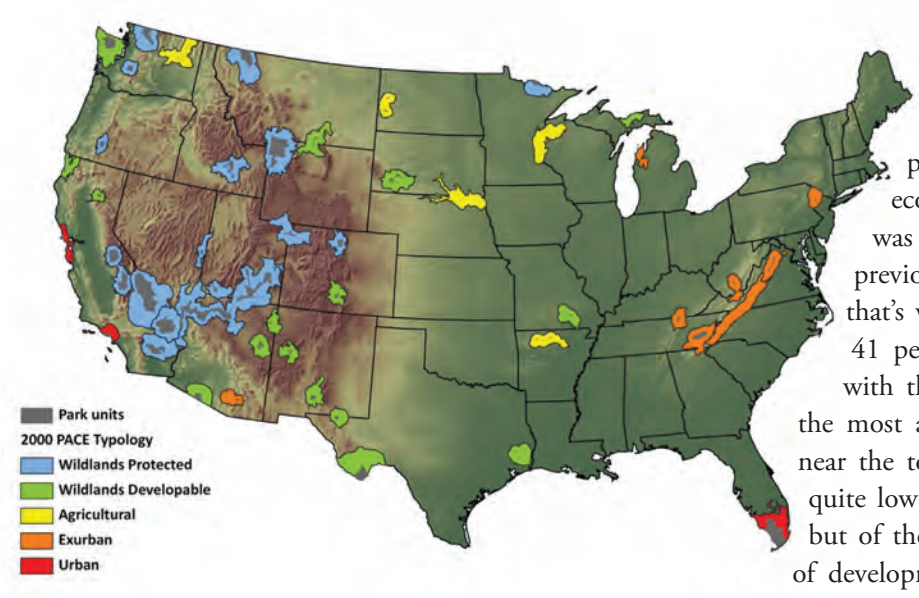

Figure 3. Results of land-use cluster analysis for 60 national parks (Davis et al. in prep.).

impervious surface and roads and change in those from about 1900 or so. Basically, we'd like to show how Yellowstone stacks up relative to other parks in terms of all of these land-use metrics…but before doing so I need to point out that in doing this kind of analysis you have to define what area around the park you're going to do the analysis for. We spent a fair amount of time coming up with a way to do this. In particular, our conceptual model is that these national parks are often connected to some larger surrounding ecosystem through migratory animals and through source/sink dynamics and through fire and these sort of things that I've been talking about. And land-use intensification in that surrounding ecosystem can alter those flows and lead to degradation of the national park. What we set out to do was to quantify and come up with objective criteria to map that surrounding ecosystem. I won't go into any details, but we used criteria related to watershed, to disturbance, to crucial habitats, to species area relationships, and to edge effects from human development.

What we're calling "park-centered ecosystems" show how many of the criteria overlap and where we think criteria overlap…we have high confidence that that's a really important place. But these tend to be fairly large for some of the parks and they reflect what we think of the area around the park where land-use change could be expected to have impacts within the park. So, that's what we used as the area to quantify land-use change.

Comparing Grand Teton and Yellowstone to the mean for the 60 parks in total…one thing that really stood out was the percentage that's in private land. The actual park-centered ecosystem for Grand Teton–Yellowstone was actually quite a bit smaller than we previously thought…some 6 percent, and that's way below the mean for all parks of 41 percent. And when you list the parks with the least amount of private [land] to the most amount, Yellowstone's right in there near the top. Population density is also rather quite low relative to the average for all parks, but of the lands that are private the intensity of development is fairly similar to the average for these other parks. So, we're largely a wilderness park because there's so much public land, not so much because there's relatively little development here on those private lands.

We used statistical clustering techniques to try to put those 60 parks into groups that made sense in terms of their land-use topology or land-use attributes, and the classes that we ended up with were called wildland protected areas, wildland developable, agriculturally surrounded parks, exurban surrounded, and urban parks [Figure 3]. And again, I won't go into any of this here, but point out that Yellowstone–Grand Teton are in that wildland protected class, as are many of the intermountain area parks. These parks are most distinguished by this majority of public land and from that protected area–centered ecosystem with relatively little ag. The private land is largely undeveloped, but that's changing quickly, particularly with exurban development. The types of issues that are fairly unique to these parks are trying to maintain or restore the land species that are present there. That's also true of the wildland/ecological processes like fire management. Wildlife-human conflicts like bear-people interactions are quite common here, spread of disease like brucellosis…many of these parks because they're in harsher western landscapes have the private land in the more equitable part of the landscape and, hence, protection of those hot spots is a particularly important issue. Some of the mineral and gas development [and] resource extraction are important issues.

I guess the main message here is that Yellowstone really stands out as special among all the parks in the country as being really emblematic of this wilderness/wildland–type

protected system. It's got the full complement of native species and even parks like Rocky Mountain and Sierra-Yosemite are dependent on Yellowstone for source areas for things like wolverines. So, again, the park has a really special role nationally and that's all the more reason why trying to sustain it is important.

So…so lastly, we've talked so much about how people affect natural systems; let's try to step back a little bit and ask "is there a feedback loop?" and "what's the whole system look like?" Various people at this conference have mentioned this concept of this coupled natural/human system. It's a term that getting a lot of attention lately, and it's really meant to emphasize these feedbacks. Of course, the way humans affect natural systems is through land management and other impacts as I've talked about, but the feedback involves certain things like goods and services including those natural amenities that Liz Shanahan mentioned earlier this afternoon and some others…as well as risk involved with disease and fire and so forth.

This model is really particularly applicable to our system because we've said that we're [a] natural amenities–based system, but a lot of the people that are moving here are doing so because of the high quality of the nature and presumably they're getting positive feedback from those natural amenities in terms of things like values of their properties, and so forth. And so, the real question is: how do you sustain a natural amenities–based system, one that is very different from a traditional system where natural amenities aren't part of the equation? You know, it's past population growth, access to transportation, etcetera.

I think there are two scenarios that are most obvious. One is what you might call "love it to death," and that is the people that move here because they're so much attracted to the nature just use it too hard…too many rural homes, too many interactions with bears…and it leads to a degradation of the natural system and a decrease in those natural amenities. But, does the population then drop? I suspect not…I suspect once a town reaches 100,000 it's going to grow no matter what the natural amenities are and take that more traditional route. So, my question would be: what would prevent a Bozeman from becoming a Salt Lake City in our lifetimes? I think it's exactly as we would expect. I think there's an alternative possibility and that's what we would call "love it to health." Which is basically to see it as a unique type of system…natural amenities–based system where the challenge is to maintain those natural qualities that are so important to the residents in terms of their quality of life and to their livelihood and to their property values and so forth…to come up with ways to do that.

What are some of those factors that [determine] whether we sustain the natural system or degrade it? Well, we know that it's related to policy. There's been a huge amount of discussion about that, like land-use planning, and we know that in Greater Yellowstone there's been very highly effective land-use planning in many parts of the system leading to, for example, dramatic increase in conservation easements in really high priority places. So, lots of progress there. We know that our effect on the ecosystem is heavily affected by stuff from elsewhere. Markets, for example…the current recession is leading to a slowdown in exurban development. Now, there's not much we can do about that in terms of management. Population size? I won't dwell too much on this here. I sometimes like to… it's something we don't talk about. I think we can sustain Greater Yellowstone at the current population size. It's easy enough. I think we can sustain it at 700,000, but quadruple that number or 16 times that many? No way. Population size does matter. Can we think about incentive-based systems for communities to move toward target population sizes?

What I would like to spend another minute more on is this last one that relates to us and our attitudes and behavior. I think there's a real opportunity to move toward that more sustainable approach. I'll just give you an example of a study that [Liz] Shanahan and I and others are just starting on that really tries to simplify the very complex human-coupled system down to a more manageable level, and that is to deal with the people that live in individual rural properties such as this subdivision and ask, basically, "why do they live there?" To what extent do natural amenities and ecosystem properties influence why they live there? To what extent do their attitudes and values influence how they manage the property in terms of things like weeds or water or roads or livestock? How do those various property management practices influence the ecosystem? Like the likelihood that weeds will jump from a yard into this adjacent burn area, this logged area, and really become established in the wildlife? Then, how will that affect the natural amenities and their value and how they're perceived back by the people? Might the appreciation of natural amenities get eroded if people tend to degrade the system? Or, if they enhance the system, might those values increase?

Those are the kinds of questions we're asking. And then, very importantly, we're asking: if people are provided good information on these connections, might

they manage their properties differently in order to have a lighter touch on the landscape? If rural homeowners are taught what the weeds are in the system that are a problem and how can you manage them effectively and try to minimize them jumping in the wildlands, will people be more likely to use those practices and limit their effect on weeds?

If these hypotheses are correct, they offer a basis for living more sustainably on the land. And this would apply to exurban homeowners to backcountry recreationalists and the many ways that we interact with nature in this system. To do this kind of work, these are the kind of people on our team: political scientists, economists, education specialists, weed people, system modelers, statisticians, ecologists…and I think that this really represents that a real integrated approach is required to tackle these types of problems. I think there are great examples of this right out of Yellowstone Park. Basically, the way the park teaches people to interact with bears in the backcountry is a fabulous example of a highly effective education program that leads to a dramatic reduction in the negative interactions in the park between bears and people. I think there's real hope for this.

Okay, so just to close out then, what I've tried to communicate is this system is special because it was so wild and so remote that it took so long to develop. And relative to other parks across the country, this one is really special in that regard. We've got special obligations to the nation in how we manage it, but this wilderness character is now attracting a bunch of people and it's really going to be challenging to maintain the natural part of the system under this increased number of people and land-use intensification, particularly with climate change. We probably have a real opportunity to try and be creative in more sustainable approaches to the system that involve land-use planning, but then also involve questions of population size and involve questions of education and human behavior.

So, thanks so much for your attention and I'd like to just thank these colleagues and students and these various NASA programs for their support for this work over these years. Thank you.

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