This year’s lectures, “Biodiversity in the Age of Humans” will be given by three of the world’s leading experts in the study of biodiversity and conservation biology. Dr. Anthony Barnosky, of the University of California, Berkeley; Dr. Elizabeth Hadly of Stanford University; and Dr. Stephen Palumbi, also of Stanford University. The third lecture is titled “Rescuing Species.” And now, Dr. Elizabeth Hadly.

[applause]

[HADLY:] Thank you, and thank you for coming back. I know I was a little depressing in that first lecture. And in some ways this next lecture, it’s not like a complete turnaround, however, what I want to do is detail some of the work that we’ve been doing, combined with other people around the world, to really illustrate how biologists are learning more about the species that are threatened. And the things that we learn are enabling us to kind of come up with alternative strategies for rescuing those species. And I also right now want to point out that I really admire the teachers in this room, and having just gotten two of my daughters through high school, I know how hard your job is, and I have to say it has got to be one of the most important things to do in the world, so thank you very much.

Okay, so I told you in the previous talk a little bit about the kinds of threats that ecosystems and that species face, but I want to break it down a little bit more. So I told you that we are pretty good at just killing individuals, we’re also clearly good at transforming habitat, native habitats, natural habitats, into the kinds of habitats that we use to feed us and to support us in the way that we’ve become accustomed. And I also mentioned to you about the challenge of climate change and losing connectivity. All of these impacts, while they are challenges for ecosystems and for species in those ecosystems, they also provide big challenges to populations within species and genetic diversity.

So the first animal I want to tell you about is the Iberian lynx. It’s found in Spain. This animal is the most endangered cat in the world. This animal is endangered for a variety of reasons, but it turns out it’s ... unlike the other European lynx, this animal hunts in open scrub habitat, which is being lost, it also specializes in a European rabbit, and in the case of this animal the rabbits have crashed in its range a few times and it’s not very good at shifting to another prey. In 1900, this was the geographic range of the Iberian lynx. By the year 2010, we have two populations left. In fact there are now today, there are somewhere less than 250 individuals, so two populations with 73 and 173 individuals in the year 2010. That’s not very many to sustain a species. And that process by which you go from an intact large range to just a few individuals is what we know of as a population bottleneck.

Well why do we care if there are just a few individuals of a species left? And you could imagine those 250 individuals only have those 250 individuals to choose to breed with. So let me illustrate this with these marbles. So if you have for your initial population say the year 1900, the Iberian lynx have a large range with many thousands of individuals, there’s a lot of genetic diversity in that species range. And
what happens after a bottleneck, when the population is culled? It’s very low. Just imagine grabbing those marbles. You can’t grab all that diversity. And so all that diversity disappears and you’re left with whatever by chance you happen to grab: a smaller amount of genetic diversity than what you started with.

Now even after you manage to somehow grow the number of individuals by breeding programs, conservation efforts, you will not reclaim this genetic diversity you’ve lost. And the reason is because extinction, or the death of species or individuals happens fast, and the accumulation of genetic diversity takes thousands to millions of years. Many generations of breeding, the accumulations of mutations, and all sorts of breeding efforts between individuals in that population. So genetic diversity is a toolkit for adaptation, and that adaptation is something that’s been used by species in the past. So genetic diversity is a remnant of kinds of key adaptations of the past, but it’s also a toolkit for whatever the future throws at them. With a limited genetic diversity you have, in the Iberian lynx for example, you have increased scoliosis, you have vision problems, there are smaller litter sizes, and of those litters, those individual cubs, more of them die. There are reproductive anomalies. Those happen much more frequent in inbreeding.

So if you envision, for example, these two different populations pulled from the same giant large species distribution, they both go through a bottleneck, just by chance you’ve collected a different subset of genetic diversity in the second bottleneck. So recovery in these two situations you increase the number of individuals. Now imagine if you could take these populations and merge them. Then, while you haven’t recovered all of the genetic diversity you began with, you still have accumulated more diversity than you have in either of these two populations. This kind of merging and recovery is one of the options that biologists and conservationists have for thinking about how to manage species into the future.

So I’m going to give you a couple of examples that we study in the lab; one is the example of pikas. Pikas are ... okay, they’re adorable. They’re related to rabbits and hares. They’re tiny animals, they have a little tiny tail. They live in high elevation, high-latitude regions in Asia and North America. In North America we have two species. They’re cold-adapted, all pikas are cold-adapted. So they’ve been around on the planet more or less for about 15 million years, and they’re highly diverse in Asia, so there are 30 species total, and only two in North America. These animals have resting body temperatures of something like 104 degrees; ... imagine that in us. They basically live with fevers, but they live at these really high-elevation cold areas. They don’t hibernate. They’re active year-round into the winter, even way above treeline. In North America, we’ve excavated sites in Nevada and Utah that show pikas in the middle of what’s now a desert. And those animals now are constrained to high elevation regions of the American West. So there are few mountaintops in Nevada, they’re occupied by pikas, they’re completely isolated from other pika populations. Going down even a little bit is lethal for them, they could not move across that desert floor, so there are little islands of pika populations.

But guess what? Global warming is pushing them up even higher. Why? Pikas can’t live in temperatures of even 75°. What we consider a perfect day, pikas consider lethal. So the current elevation range of pikas, especially when you go up to the species in Alaska, it goes all the way down to
sea level, but in North America, in the 48 states, the future elevation range of pikas is moving up. As a matter of fact, in the last 50 years, many of those great basin populations have been extirpated because of warming temperatures and some other features as well.

So pikas are running out of real estate. Our future projections of pikas based on warming models for just the next few decades are a few populations left in the Sierras in California, and then again isolated populations in the southern Rocky Mountains in Colorado, and in Wyoming. Pikas are headed out. But pikas are very diverse in Asia as I mentioned. And what I want to do is draw your attention to the southern part of the green range in Asia, which is centered on the Tibetan Plateau, including India and Nepal and China. So this is a photo from one of our field sites in the Himalayas of India. This site is way above treeline, it’s very stark, and there are pikas here. This is the kind of environment they live in. As a matter of fact the Tibetan Plateau, ... the average elevation of that place is around 6,100 meters, 20,000 feet. We don’t even have mountains that high in the lower 48, and so pikas are diverse here. And you’d think, oh gosh, lots of room to move as they go up in elevation with warming temperatures, which in fact they’re already doing. They’ve been very little studied in this region of the world.

So extreme elevations, however, present alternate challenges. And that is that, if you go up even to Denver, Colorado from living here, you’ll notice you’re a little bit out of breath. The Mile High City has only 83% of the oxygen that you find at sea level. When you start getting to, say, Denali, Alaska, 48% oxygen level than at sea level, and the highest human occupied city is in Peru at 5,100 meters, again, over half the oxygen level we’re used to breathing at sea level. Mount Everest in Nepal only 30%, so surely you’ve read about how mountain climbers increasingly rely on oxygen canisters to expend any effort up there. When you’re at high elevation you move slowly, you breathe hard, and although we can adapt a little bit to it we can’t live there permanently. Pikas can.

However, not all pikas can, and this is something we’ve learned in our work in the lab. So one of my graduate students has been out there trapping these animals, live trapping them, she releases them and she’s been looking at where pikas live. So all three in green, all three of these are groups of pikas. They’re called clades, they’re families of pikas. They’re all pikas, but they have different names to them: the pikas, the Ochotona, and Conothoa clades of pikas, and only the Conothoa pika can extend to these extreme elevations characteristic of most of the Tibetan Plateau. It turns out that they happen to have adaptations, ... this is an area of active investigation in our lab, to try and understand what these molecular adaptations to their metabolism, what they are that allow them to live at this extreme elevation.

Now what does that mean and why do we care about pikas? Well, it means that not all pikas will respond to global warming in the same way. They’ll all kind of be forced in some ways to not occupy those lower elevations, but not all of them can expand to high elevation regions. And why do we care about this little critter? This animal is hunted, there are active poisoning campaigns across the Tibetan Plateau. Millions of hectares have been poisoned to try and get rid of this animal. In part to make room for grazing animals.
But why do we care about this pika? It turns out pikas are what we know of as keystone species. They’re ecosystem engineers that are really important for other species in this entire Tibetan landscape. The Tibetan wolf; weasels; the snow leopard turns out to rely on pikas for its prey as well; bears; and the Tibetan hawk. These predators, there aren’t a lot of small mammals at this extreme elevation and it turns out that this is the only one of those small mammals that’s active year round. So these predators really rely on this food source.

They influence the plant community; they’re herbivores, they graze a lot and remember they’re active year round, and what do they do? They have to collect a lot of vegetation to persist over the winter. They create little hay piles and they influence what vegetation is grown around where they eat. That in turn influences the grazers such as the Tibetan yak that are native to this system.

Their burrow construction also is important. It turns out that those burrows, they actively dig a lot of burrows, live underground, some of them live in talus slopes and rock piles, but often they build burrows as well. And those turn out to be important habitats for lizards and birds. There’s one bird species that relies entirely on those burrows that pikas dig for their nests, and for protection from predators as well.

And then most importantly from our perspective is that these burrows provide water filtration. So as rain comes down on this kind of dug up ground, it infiltrates. There’s what we call bioturbation. The pikas turn up and move the soils and nutrients around, and they allow water to penetrate deeper instead of just running off. Why do we care about that? We care about that because it’s storage. It turns out the Tibetan Plateau and the rivers that originate in that plateau are remote, very, from our perspective, little impacted landscape, basically are the source of water for almost half of the planet’s humans. A very important ecosystem service this little animal provides to us.

But it’s not these keystone species, these ecosystem engineers that are important to save. Somebody asked this question earlier today; so let’s talk about charisma. So who wins the mammal popularity contest? Does anyone know? Who’s the most popular animal on the planet ... mammal on the planet? Pandas? Close, but no. Dogs? No. Humans? No. We don’t win votes for mammals. It’s the tiger. The tiger, year in and year out, turns out to be the most popular mammal on the planet, and tigers are on the brink, okay. They functionally don’t serve a lot of ecosystem services where they’re found because there’s so few tigers. We are responsible for the fact that they’re at the edge of extinction. Tiger numbers have dwindled along with their habitat. So prehistorically there were over 100,000 tigers. By the year 1970 we had 40% of their habitat left, and we had less than 40,000 tigers left. As habitat declined and the number of tigers declined, tigers started going extinct in populations around the world. The ‘40s, they were extinct in Bali, in the ‘70s, extinct in Central Asia, in the 1980s, they were extinct in Java, and in 1990s, they were extinct in South China. Now there are 3,200 tigers left. This is the historic range of the tiger, they’ve lost 93% of their historic range. This is their present range today. Now what does this look like? A mosaic, a patchwork of populations, and in fact that’s what it is.

So that’s what I want to tell you a little bit about. So if you’ll note, so the crop and pasture again is shown in this magenta color and green is the present range of tigers. Now I’m going to fade away the
present range and what you’ll see, like look up there in Siberia, basically where we don’t have crops and pastures, tigers can persist. And it’s even more extreme when we think about human population density. So darker colors here, the darker blue is high human density, and lighter colors are lighter human densities. So you can see right there in northern India, enormous population density, in China, enormous population density, and as we fade the present range of tigers out, again what you see are that tigers can persist where humans and their crop lands are not. So protected areas are clearly important for tiger populations.

Now what I’m going to do is I’m going to work through what we know about these separate populations, and I’m going to talk to you about genetic diversity. I’m going to show you a series of circles connected by lines. The circles are scaled by the numbers of individuals we sampled for their genetic diversity, and based on this particular marker we’re using, this kind of sequence that we’re using, what you’ll see is that some of these tigers have no genetic variation that we know about, and others have much more. Siberian tigers are found in remote areas of Siberia obviously, and there are only a few hundred individuals left. They’re almost all identical. They are very distant. These Siberian tigers, and I’ll point out to you, every one of these tigers I mentioned, you might have heard of all of these, they’re all the same species, but they’re managed differently. The Indo-Chinese tiger. This tiger prefers rolling hills and forested habitat. The Malayan tiger and the Sumatran tiger, a little bit more diverse right. You’ll see the connections, the lines here, show how divergent these particular groups, these populations are from each other. The Sumatran and Malayan tiger are small animals, and instead of living on large prey like the wild boar, they live on tiny animals that are in dense tropical forests. They look slightly different and they have different habitats adapted for different environments. And then the Bengal tiger, is more diverse in terms of their genetic diversity than the rest of these tigers, and yet there’s only 11% of Indian tiger range remaining.

So India, in spite of this incredible human population density, has managed to preserve a lot of prehistoric genetic diversity of the Indian, the Bengal tiger. Now I’ll point out, this Bengal tiger extends from open grasslands to forests, it relies almost entirely on deer, and some of them, the ones in the center here, in between Indo-China and Bengal, these animals live in mangrove forests right on the edge of the coast. They’re incredibly good swimmers and they move from mangrove forest to mangrove forest in their hunting. So they all have different adaptations and yet they’re separate from each other.

What about global change? I want to put that question in your head. So let’s go to tigers and think about, how do we rescue tiger genetic diversity? How do we make sure that these tigers are not headed for their own independent extinction event? And in fact we’ve lost many tiger populations I haven’t described to you. I showed you the loss of the Javan tiger, the Bali tiger, the Caspian tiger we’ve lost, but these tigers that we have presently are just a few numbers. The largest number of tigers are in India, just over 1,000, everywhere else there are just a few hundred individuals, interbreeding with each other and all the problems that happen with that. So envision each one of these populations as distinct and separate and with limited genetic variation. Independently they’re all headed for extinction.
So a bold proposal that has come from some genetic modeling studies we’ve done in my lab suggest, why not try and merge individuals across these populations? Gosh, this is a radical idea. And why? Because these populations now are managed as completely separate entities. The Bengal tiger is an Indian tiger; the Malayan tiger is a Malaysian tiger; the Siberian tiger ... recently an individual created an international incident when it swam across a river into China. They are iconic images of these countries. It’s a difficult thing to think about how we would do this, but there are ways. There are ways. Assisted reproduction: there are ways to merge the genetic diversity of these populations. We can never hope to recover the geographic range of the previous tigers. You saw what human density is like and you saw how we’ve transformed the habitats, but we could inject diversity into the populations we have remaining.

And I have to point out the tigers in the zoo are important too. Do you know there are more tigers in zoos than there are in the wild? There are 5,000 tigers left in zoos. It turns out that, if you think about the geographic range, the extent that tigers actually occupy, think about the adaptations of the Bengal tiger compared to the Siberian tiger. In times of global warming, where would you like to put your money on who’s going to survive? It’s the genes likely adapted to these southern warmer environments that are likely to survive, not the ones adapted to remote areas in Siberia. Zoo tigers are going to be important for the survival of the tiger as well. So biodiversity is at risk at every level.

And what I’ve described to you from everything from protecting habitats to creating corridors, so animals can move back on their own, to creating assisted migration of reproductive gametes between areas, to keeping the protected areas we have, limiting poaching, and the big challenge is staving off climate change. Every one of these levels is important for biodiversity. Every one of these levels has a different kind of set of challenges and different sets of solutions to help deal with it. And with that I’ll answer any questions.

[applause]

[STUDENT:] This question was actually from your previous talk, but it kind of relates. Do you think like ignoring any moral obligations that we should preserve animals that are extinct in the wild, except in zoos, like, if there’s no hope of reintroducing them, do you think we should keep that species alive because it kind of has, like, environment harm, like keeping it alive in the zoo causes pollution and stuff?

[HADLY:] So that’s a really good question, and there’s actually a whole field called rewilding, where people of thinking of not only keeping the zoo animals alive, but some people are proposing to de-extinct species, to come up with ways to kind of bring back species like the passenger pigeon that are already extinct. And I have pretty strong feelings on that, and the reason is because I think we’re just not even doing a good enough job taking care of the species we have out there in the system. So yes, I think genetic reservoirs in zoos are important, but I really, really think and advocate that species in the wild are even more critical. I think we can have a myriad of techniques in keeping species alive in zoos may be important for some iconic species that we want, but on the other hand we’ve got to keep these wild animals out there and interacting in the wild. Really good question. Here?
[STUDENT:] Do you think if we don’t maintain biodiversity and if climate change continues to worsen that we could be potentially facing our own extinction?

[HADLY:] Well, sure. I showed you, I showed you what happens if we happen to get 27 billion people on the planet. I mean how could we support ourselves? We already occupy, with our seven billion people, we’re already basically co-opting the primary productivity from 51% of the planet, so how in the world would we fit 27 billion people? So I think humans are going to survive. However, I think we have some big challenges to decide what kind of future we want. And that is really something you guys are going to be talking about well into the future. Really good question. Up there?

[STUDENT:] How difficult would it be to engage in the merging of genetic diversity of tigers?

[HADLY:] You mean in what I proposed up here?

[STUDENT:] Yes.

[HADLY:] It’s something we’re starting to talk about. This paper that we produced about this model about hypothesizing that this might be a way to rescue genetic diversity of tigers and stave off major inbreeding and perhaps their demise. Something that’s been picked up as a potential opportunity by the U.S. Fish and Wildlife Service, for example, they wanted to know what our methods were and how we did it. We just published this paper. So I think it’s possible, and I think what it’s going to take though is coordinated efforts between countries. So the tiger has a range that encompasses so many different countries, we’re going to have to get everyone on board, and this is what’s provocative. We have to sink the subspecies to save the species. We have to say good-bye to the Siberian tiger or the Bengal tiger to save the tiger as a species. That’s a decision we have to make. And I think that’s all the time I have for questions. Thanks very much for your attention.

[applause]