So at this point, why don't you stop the video for a second. And in your field, write down a couple of notes about kinds of models that people use to make predictions for decisions. Or at least that they might use to make predictions for using and decision making.

Now, if you're an ecologist, you might write down models about ecological phenomenon, or if you work with ecological phenomenon. Maybe you're not an ecologist, in which case you might write down the names of, or some kinds of models that people in your field use. But just take a few minutes here, stop the tape, and write down those. And then we can continue, you can hopefully think about those a little bit as we go forward from here.

OK, so let's talk a little bit more about examples of models. And we're going to distinguish between two kinds. We're going to distinguish between conceptual models and predictive models. And maybe you'll see some of the names of the kinds of models that you wrote down that you use, or that people do use in your field for making predictions.

And what I'll show you here is a list of predictive models that people will often use in ecological settings, or population management settings, for making predictions. But we'll start by talking about conceptual models.

And conceptual models are more general. They can be used in any kind of setting to make predictions. Or to at least start us down the path of ultimately making predictions by helping us to frame up the system that we're working in and the elements of the model that we might ultimately want to include.

But you might now find that when you wrote down ideas of models, you wrote down things like population models. So, people who are managing populations or species often will use population models to make predictions about the impacts of different kinds of actions. People also often use habitat models, so thinking about, say, how buying or managing land would impact the quantity or quality of habitat.

We also sometimes-- and some of you may be familiar with a set of modeling tools that come under the general concept of Bayesian belief networks. And Bayesian belief network models are really particularly good at helping us think about how uncertainty influences our system. So there's a wide array of

different kinds of predictive models that people use.

Conceptual models are really good for helping us think about the different elements that we might need to represent ultimately in a predictive < to, again, frame our decision and help structure our analysis, be transparent and communicate our analysis to other people. Once we understand a system that we're trying to model with a conceptual model, then we often will move into some of these more field-specific kinds of predictive models, like population models, habitat models.

If you're an economist, you might have written down the names of certain kinds of economic models. There are different kinds of management models that people use. So there's a fairly wide array of different kinds of models that people use to make predictions. We're going to focus today in more detail on a wider tool of conceptual models that are useful for helping us structure our problem and our analysis.

Before we do that though, let's talk a little bit about the criteria or the questions that we ask to help us to decide what kind of model either to build or to use in developing a decision framework and making predictions. So we might ask questions before building a model, like ultimately what's going to help me make the best predictions?

Ecological understanding, it's really important to recognize, is not the focus unless that ecological understanding helps us improve prediction. So, for example, we don't necessarily need to build a model that includes all of the elements of the lifecycle of a particular species if only some elements are relevant in the context of the decision that we're making. We might ask questions like what are the pertinent model variables? And remember, we talked about that model inputs are essentially the alternatives that we have.

So what we're going to do or not do influences what we put into the model. What we're trying to gain, or what we're trying to achieve, that is our objectives. That should tell us something about what the model output should be. So we make predictions about our objectives.

We also want to ask what uncertainty we need to include. If we have really important uncertainty about our system, we need to recognize that when we build our models. And so maybe we need to ask will this alternative be effective depending on how that uncertainty actually is resolved? We have to incorporate uncertainty, but it's also important to say that we don't necessarily need to incorporate all

the uncertainty that we have about a system. We only need to really incorporate the uncertainty that affects the decision.

We also often will need to think quite a bit about the amount of complexity that we need to include. So let's take an example like the lifecycle, the annual cycle of the Red Knot. So this came up in a decision problem that basically involved the harvest of horseshoe crabs in Delaware Bay.

Delaware Bay is an important stopover site for Red Knots on their way from their wintering grounds in South America to their breeding grounds in the Arctic. They stop over at Delaware Bay, and they primarily, while they are there, are eating horseshoe crab eggs. So the question of harvest of horseshoe crabs has an influence on horseshoe crab egg availability for Red Knots.

So you might start by thinking about all of the complexity involved in the annual cycle of the Red Knot. But after some careful thought, you might realize that the elements that are most relevant for making the decision about harvest of horseshoe crabs are really a much smaller set of elements. And ultimately, when it comes to that decision whether or not to harvest horseshoe crabs, maybe what we really care most about is the abundance of eggs that are available to Red Knots on the beach in Delaware Bay.

And so we can take a lot of complexity about the annual cycle of the Red Knot and simplify it quite a bit. Realize we probably don't need to build a model that includes what's going on in the wintering grounds in South America in order to help us make the decision about the management of horseshoe crab harvest in Delaware Bay.

OK, so we talked a little bit about how we make decisions about what kinds of models to use. And we talked a little bit about certain kinds of predictive models that we might use in ecological settings. But let's talk a little bit more at length about conceptual modeling tools that are used primarily to help us structure our analysis, be transparent about our analysis, and to help us think about the kinds of predictive models we might ultimately need to build.

So let's start by talking about influence diagrams as a conceptual modeling tool. So influence diagrams conceptually make links between actions and objectives. And we distinguish and influence diagrams between relationships that we can and can't control. And we indicate this kind of information through the use of nodes and arrows. And there's different kinds of nodes in influence diagrams.

We think about decision nodes. So these are situations where we have a choice. We can decide to do A, B, or C. Chance events, things we don't have at least complete control over, like weather, or extinction, lots of different kinds of chance events.

Outcomes, so we have outcome nodes. And really, those are our objectives. What are the outcomes that we care about, and those are ultimately our objectives.

And then we often will also use calculation nodes to represent the interim steps between the decisions and the outcomes that we care about that aren't really represented as chance events. So, for example, outcomes are modeled or indicated by hexagons. So our outcome nodes are hexagon nodes, so these are our objectives, these are the things we care about.

Rectangles are our decision nodes. We can choose to do A, B, or C, decision nodes. Chance nodes we represented as circles, and these calculations are constant nodes we represent as rounded rectangles.

So let's talk a little bit more about the kinds of relationships that we can indicate using these kinds of influence diagrams, the different kinds of nodes, and then the directionality of the arrows. Well, in influence diagrams we represent relationships that have to do with relevance, or the sequence. So if we look at the diagram on the left side of the page here, we're representing relevance.

So evaluating the chance node R, which is whether or not there's rainfall, and the decision node B, whether or not there's a controlled burn, understanding each of those things, those events, those nodes, is relevant to evaluating the chance event in the chance node F, so whether or not there's a wildfire. So there's relevance in understanding rainfall and controlled burn to understanding whether or not there'll be a wildfire.

Another way to think about it is sequence, things happen first, second, third, and so on. If we look at the right side, the sequence of events, whether or not someone completes his homework and whether or not there is a rainstorm, say, which is denoted by the circle with a W in it, the chance node with a W in it, weather. Those things have to be resolved first in the sequence before we know whether or not we're going to play soccer later on in the day.

So whether or not we complete our homework, and whether or not there's a storm event, resolving those events first allows us to make a decision about whether or not we can play soccer in the decision node S. So again, the relationships that we represent with influence diagrams are relevance and

sequence of events.

We can look again for an example of a influence diagram at the crane nest failure example that we talked about in the Alternatives Module, Module D. Again, we talked about this idea of crane nest failure at Necedah National Wildlife Refuge. We had ultimately an objective which was the status of the population, and we represent that here with an outcome node, a hexagon.

And we have some chance events that occur in-between our ultimate population status. The actions that we can take, things like drawdown, insecticide treatment, and so on. So we can use again here, taking these actions has an impact on some chance events which ultimately has an impact on some objectives that we care about.

It's important to recognize the difference people oftentimes are more familiar with system models. And those are different kinds of models than influence diagrams, although we also often will build system models before we get to the point of building predictive models in making decisions. But there is a difference between influence diagrams and system models.

So in influence diagrams, the nodes and the arrows represent our belief, or our knowledge, about how different variables affect other variables. In system models, the nodes we have actually represent stocks of quantities. So, for instance, we might have a node that represents the abundance of a population. And the arrows represent flows into and out of those stocks. So if we're thinking about a stock that represents abundance, we might have flows that represent things like births and deaths.

Oftentimes we can represent different kinds of problems using both influence diagrams or systems models. But we are capturing different kinds of aspects of the problem when we use those different kinds of tools, so let's look a little bit more at this. horseshoe crabs and shorebirds, which we talked about a little bit earlier in terms of simplifying more complex models. So here we have an influence diagram where the thing that we ultimately care about, our objective, is to maximize the horseshoe crab eggs on the beach for Red Knots.

And we have some chance events that have an influence on that. The weather has an influence on horseshoe crab eggs, and we have some decisions that have an influence on that. Whether or not we allow the harvest of horseshoe crabs or not has an impact on the number, the amount of horseshoe crab eggs that are available for Red Knots.

Now let's contrast that influence diagram where the nodes represented decisions and variables, outcomes that influenced each other with a system model of the sort of similar system. But here we have a node that is the number of spawning crabs, so that is a node that is actually a stock. It's truly the number of spawning crabs.

Now, that has an influence on things like the surface eggs which, again, is the thing that we care about. But using this kind of a system model, we can think about how things flow in and out of that spawning crab stock, births and deaths of crabs, the harvest of crabs and so on, influences spawning crabs. The important point here is that both the system model and the influence diagram are ways to help us structure our analysis, understand our problem, visualize our problem, talk about our problem with other people. And ultimately, they both should get us closer to building quantitative predictive models of our system.

So let's take a minute and try a little example. We have a question about whether or not to establish a reserve. So we have some endangered species that we would like to keep from going extinct, and we'd like to possibly establish a reserve or maybe not. Our objective is to maximize species persistence. So take a minute and stop the video, and see if you can develop your own influence diagram for this question.

OK, so let's do this together. Let's go through the process of building an influence diagram. So let's start with our objective. We care about the status of the population of our endangered species. We care about whether it's extinct or weather it persists. So we might sort of shorthand indicate our objective as this population's status. And we can then build, if we start at the right we can build to the left.

Population status is affected by extinction events. If there's an extinction event, then the population is extinct. If there's not an extinction event, then the population persists. So we think then that we might be able to influence the population and the extinction events by building a reserve. We have a decision node, create a reserve. Now, creating that reserve influences the chance in the extinction events chance node, and so we represent that with a arrow going from the create reserve node to the extinction events node.

Creating a reserve might also affect the population status in other ways, and so we might also represent a connection directly from the create reserve node to the population status Node. So, for

example, perhaps there's more habitat, so overall the population starts at a greater level. Or maybe we're able to create a reserve that allows us to have multiple, somewhat separate populations, so some kind of a meta population model. So depending on how we conceive of our system, we might have an arrow also going from the create reserve directly to the population status.

But understanding whether or not to be create a reserve influences the chance event in the extinction event's chance node and ultimately influences the objectives in the outcome node population status. So hopefully, you developed something similar to this, and you can see how maybe using an influence diagram for one of your problems would help you to think about the relevance in the sequence of events, and how to tie, ultimately, your objectives together with your alternative actions.

Let's just summarize what we've talked about in this module. We talked about models and how they're used in decision making. And the primary message here is that we use models to link our objectives to our actions.

So if we make statements like if I take this action, then the outcome in terms of things I care about, my objectives, will be X. And more completely, we can think of three different ways that models help us to make this link between our objectives and our actions. Models help us to structure the analytical problem, to see the different steps in the analytical problem that we need to complete. Models help us to lend transparency to our analysis so that we can communicate it to others and to also help others to sort of help us make our model better. And to ultimately and most importantly, models allow us to predict the consequences of different alternatives.

Now models can be very complex, or they can be very simple. And it really depends on the particular decision problem, the other elements of the decision framework, the objectives, the alternatives, and so on. And really how important it is that we be very precise in identifying the correct action to take.

We did talk at length about a particular kind of model, a conceptual model. And we talked a little bit more about that because those kinds of conceptual models help us to, in particular, do those steps that managers are often involved in doing, structuring the problem and lending transparency to the analysis. And also as sort of a first prototype of a perhaps more involved predictive model.

And the conceptual modeling tool we talked about was, of course, influence diagrams. And those influence diagrams can help us to communicate about the model we have of our system with other

people on our team or with other stakeholders, and to concisely convey a lot of information to help us then go on to further steps for actually developing predictions.