# Ecological Forecasting Tools

**Moderator: Courtney Chambers**
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Courtney: Now I'm going to give you today's speakers on ecological forecasting tools. Dr. Todd Swannack is a research biologist at ERDC's Environmental Laboratory in Vicksburg, Mississippi. His research interests cover a wide range of issues including ecological systems modeling, ecosystem processes and population dynamics of threatened and endangered species.

He applies his research to a range of projects, basic and applied, including modeling theory and application, ecosystem restoration and oyster dynamics. He is also co-author of the textbook Ecological Modeling: A Common-Sense Approach to Theory and Practice.

Our second speaker, Christy Foran, is also a research biologist at ERDC's Environmental Laboratory, but stationed in the New England district office. Christy assists with review and development of decision analysis tools, with a wide range of applications including multi-criteria decision support for cumulative impacts; adaptive management for environmental restoration; and prioritization of resource allocation.

And we're very thankful for you're willing just to share with us today. So without further ado, Christy, I'll give you the presenter rights and we can begin.

Christy Foran: Thank you. Thank you, Courtney. This is Christy Foran and I'm presenting today with Todd Swannack. Our topic is ecological forecasting tools and planning of ecosystem restoration projects, and very pleased to be able to talk with you today about some of the work that we're doing here in the decision analysis team, and some of the thoughts we have in general about models for planning.

What we'd like to do today is do a general introduction about forecasting and planning, and then I'll be turning the presentation over to Todd, who's going to be talking about model solution and evaluation. And from that introduction, we're going to be looking at a classification system for tools that we have been using to determine how those tools perform to forecast or predict future conditions. And then we have a set of general conclusions.

And I wanted to say by way of introduction that you all are familiar with models; use them regularly. You know from your training that models are just abstractions of reality. The problems arise when you need to select the best model for your purpose. You need to select the best model relative to the objectives of the project, relative to the data availability, and relative to the resources that you have available to use that model.

When I think generally about models, I always think of the Magic 8 Ball. For those of you that aren't familiar with the Magic 8 Ball or didn't have one as a kid, it's a toy that looks like an 8 ball. It's a black ball filled with fluid, and there's a dice inside.

And you turn it over and the dice floats up to the top of the window and it gives you an answer. Usually it's yes, no, or uncertain or some function of those answers. And when you're using a Magic 8 Ball, there's three major considerations that you have to have. The first and most important thing is you need to know is what you're going to ask the 8 ball. You need to have a question in mind, and that's the critical information you need for your project.

And secondly you need to understand the form that the answer's going to take. So for example, you cannot ask the Magic 8 Ball what time will my flight leave. You have to ask it will my flight leave on time, to get an answer that's relevant to your needs.

And the third thing is the application of the model. You need to determine how that model's going to be applied to the situation, and if it's going to be applied appropriately. And I know the Magic 8 Ball that I have on my desk, I can tilt one way or another to get a second opinion out of it.

So there's three critical aspects of this model analogy -- the question, the answer and the application. And we're going to be discussing each of those today in general, with the idea that the specific application to a specific project might diverge from the general conclusion.

So our objectives are first of all to overview the model type, selection and evaluation. This is Todd's area of expertise and what he'll be talking about. And in general this addresses the first two issues of the Magic 8 Ball -- what question or what information needs do you have from the model, and what's the form of the answer that is going to be appropriate for your information needs.

Then I'm going to be outlining an approach for the classification of models, which has allowed us to look at the range of complexity of those models. And we wanted to do that in order to determine how they work as forecasting tools for planning.

And finally we have an additional objective, and that's to look at these models and to talk to you in this Webinar to get a clear perspective for us as ERDC researchers of the forecasting needs of planners.

We understand that the solution that you're applying to your project should only be as complex as the needs that you have for that project. We're going to be talking in generalities today, but we welcome the opportunity to talk to you about specific projects and bring this discussion back to us on a case-by-case basis.

I wanted to start by just giving a little bit of context of ecosystem restoration, and this will not be new to you as the audience. But I recently had the opportunity to look at some of the completed restoration projects from the Corps in Rhode Island.

And I was really struck at this beautiful salt marsh, the Galilee Salt March, constructed by the New England district, finished in 1997, and was awarded a number of prizes including a 1999 Coastal America Partnership Award.

And you're well aware, I'm sure, that the Corps of Engineers restoration budget is nearly $500 million a year, and that there are multiple ongoing projects usually within a region, sometimes within a state. And often those restoration projects are species-specific or habitat-specific as opposed to being ecosystem function oriented. So they're looking for eliminating an invasive species or encouraging population of another individual species.

This is the Corps' planning beehive. It's been designed to allow us to think critically about the specific needs of each individual project, and deliver the best plan of action. And what I wanted to note on here is that there are two kinds of ecological forecasting mentioned within this beehive. Let me see if I can get this pointer to work.

In the second step here, there's the need to inventory and forecast conditions. And this is an initial application point for forecasting. So here's the opportunity to project the conditions that are going to exist in the future. And this is where models are generally selected and used to formulate alternative plans.

Once you have a range of alternatives in mind, you have to thoroughly evaluate each of those alternatives. And this is where forecasting occurs for each individual alternative. So this is the with- and without-plan of action of what you expect to happen in the future.

This second test usually involves the output of a model or several models. And so this is the area of the planning or the output of the model that is critical for determining the best plan.

So how are those models selected? For this I'm going to turn over the presentation to Todd.

Todd Swannack: All right. Thanks, Christy, and thanks everybody for hanging out and participating today. So what I'm going to talk about is just briefly about how to select models, different types of models; and then go through some kind of good practice guidance for what you do when you're developing a model and then also evaluating it; and talk about the modeling process in general.

But the point is, as time goes on we have a whole lot of different models that could be appropriate for a particular project. And you have to look at the suite of models that are available, and determine if it's an appropriate tool for your particular issue.

And, you know, first you need to look at the nature of the problem, and then look at the documentation that exists for any tool that's available, and see if it's appropriate for use with your particular system.

So for example, if you're working in restoring some salt marsh and you see a forest regeneration growth model, that might not be the appropriate model to use, because it's a different system.

Models are built on assumptions. Like Christy had mentioned, they're abstractions of reality that we're doing the best job we can to try and capture some of the complexity of the ecological systems. And so every model is limited in what it can be applied for.

But the key is you need to look and see if the model captures the essential system components as they apply to your specific project. So, you know, within - if you break ecology down or environmental science down, you have a series of environmental processes that drive the system dynamics. And if an existing model captures some of those processes, it might actually be the perfect tool for a particular project.

So here are just some general model types. They're very general, starting with analytical. These are the simplest types of quantitative models, generally based on a series of differential equations. And the idea is that you can get a solution to these equations for any instance. And because they're so general, they often don't apply to specific problems.

One of the things that I'm going to emphasize today is the development of conceptual models. Conceptual models are just depictions or diagrams of the system of interest for a particular project. And they can be as simple as, you know, some pictures of like a forest and a tree and some water; or they can be relatively complicated with boxes and arrows where each box represents a quantitative value of the system.

So then one of the things we deal with in the Corps a lot are index-based models which in general determine habitat quality across the landscape. And that quality metric is based on, you know, quality for a species or quality for a particular type of community -- plant community growth or something like that. They're relatively simple representations of a system.

Simulation models are models that are designed to actually mimic real ecosystems. They're still simplified versions of ecological systems, but they're getting relatively complex where you can track individuals across a landscape or within - like within a channel, a river channel.

And, you know, typical types of these are agent-based models -- the ADH CASM suite, the ELAMs, ICM, et cetera. There's a lot of these available, and there are some pretty good tools within that suite.

Statistical models just are representations of a data set. So you go out and you collect data and you run some statistical tests, like an analysis of variants or a T-test, to determine if there's any difference among the treatment groups. So what you end up with is a mathematical representation of your data set.

And then spatial models actually consider space explicitly. They kind of are grouped with other types of models a lot like most simulation models that we see for Corps projects have a spatial component, so they are called spatially-explicit simulation models.

An index-based model can actually be spatially explicit, but it's often - I mean it's unique enough to actually pull out and consider spatial a little separately. For example, like a GIS tool is a spatial model within itself.

So in general, this diagram I'd say captures the modeling process relatively well. It's important to note that not every project is going to need a model. And that, you know, if you're using a model that already exists, you may not really focus on the model development section that much. You will use the model evaluation area, but in general this is for model development.

You come up with a plan or you have a project, and then you develop a conceptual model. You use that conceptual model as a template for your quantitative model. So when you're putting the numbers to it to actually forecast into the future, you then evaluate that model.

You evaluate the equations. You evaluate the conceptual model. And within this model development box, you see these arrows that are flipping back to the top here and here. And this emphasizes the iterative approach to modeling.

And I'll talk about this in more detail in a second. But the idea is modeling is a dynamic process.

And as you start developing a model you may realize as you get into it that your conceptual model’s not quite right and you need to go back and fix it or that you found a better equation to represent your process, a measure evaluating it so you can go back and fix it. And once you've evaluated your model you then apply it to your particular project.

So I'm going to break out each of those little boxes in a little bit more detail and just talk about good practice guidance for model development real briefly.

But so when you're developing a conceptual model, you know, you need to make sure that your conceptual model is based on precisely defined objectives.

And as you're developing your conceptualization of the system think about how you're going to evaluate the model, how you’re going to calibrate it, how you’re going to verify it because that will help you kind of fine tune your conceptual picture.

When we deal with ecosystem restoration the system can get huge and you have to decide what actually is important and what's not. For example if you're working in a restoration project in Puget Sound, you know, urban growth in Seattle obviously will affect the system somehow but, is it going to affect your particular project? So you have to kind of figure out what variables are important.

Once you get that stuff kind of written out you then draw your conceptual model. And there are a lot of different schools of thought on this in terms of how to do that.

But the basic idea is you want every arrow or box within your conceptual model to represent something that you're going to use to develop your quantitative representation that you'll use for forecasting.

Once you get this done, this is a pretty key step, you want to describe what you think your model’s going to do.

Because when you're evaluating it if it doesn't do what you think it's going to do then something's wrong.

But if you don't address that issue up front you may say oh no, no, it’s working fine but it may not be.

And then this identified data quality and quantity as you’re developing your conceptual model you're going to be aware of the data that are available for your particular system.

One of the cool things about ecosystem restoration is the people that actually have hands on experience are themselves modelers. They know how the system works and they're going to know what data are available but as you're identifying and drawing out your conceptual model you may think of something new.

And so my recommendation is upfront just draw out your picture and then go back and see what's available because you’re going to already have an idea how your system’s working. And once your conceptual model’s drawn you can go back and say okay we've got good data for this area, we don't have it for this, et cetera.

And then you want to identify how your model’s going to be used. And, you know, within this conceptual model development these steps are iterative as well.

The conceptual model is actually a pretty intellectually challenging exercise that can take quite a long time. And so you want to kind of evaluate your conceptual model as you're building it.

And so when you build your forecasting tool if you're going to forecast any kind of dynamics into the future you want to make sure that whatever math you're using is represented in your conceptual model. So if you're modeling a particular process you want that process to be represented in your conceptual model. It doesn't matter what kind of math you're using but you want to make sure that it's actually represented in your conceptual model. What that does is it creates a level of transparency, a model development that says here's our conceptualization of the system and here's how we represent it explicitly mathematically.

And then, you know, without getting in the weeds too much on the mathematics there's a lot of different types of models and everybody has their favorite kind of math to use.

I like addition and subtraction. So you want to select the general quantitative structure, time unit, and spatial scale for your model. So this is going to kind of be taken care of when you conceptualize your system.

So like you don't want to - if you're looking at again back to the Puget Sound example, if you're looking at a restoration project kind of on the southern end of the Puget Sound you don't want to simulate the entire Western seaboard. That's not appropriate and you don't want to do it for 100 years or 1000 years. You know, most of our planning studies have a 50 year time horizon. So the timescale that you need to capture should include whatever spatial processes you’re including in your model.

Another example of a time unit is if you're looking at tree growth, you know, you may not want to model every second of the growth of a tree. You know, it may actually work out so that you can use an annual time step for every five years or ten years.

Whereas if you're looking at how sediment moves through a channel, you know, you're going to need to scale down your time step.

And one of the things when you get into particularly within index based modeling is you want to identify what your equations are going to look like in general.

What I've always recommended is you just kind of draw a straight line. If this goes up this goes down or we think it's logistical, we think it's like an S shape curve or an exponential decline.

This kind of gives you an idea of what you're equation should look like. Within a lot of ecological systems we know what process we’re looking to model but we don't quite know if data may or may not be available. There's a whole lot of uncertainty associated with ecosystems.

And so this kind of helps you narrow down what type of math you're supposed to be using. And then you can estimate parameters from all equations. You can do this using statistics. You can drive your equations and all this depends on your particular project and your particular expertise.

Once you've developed your model you want to evaluate it. And this is key. Model evaluation, particularly with what we do in the Corps, is a really huge deal.

You want to make sure that your model is behaving like you thought it would. So this is verifying that your model is actually working right.

These days everything is done in the computer so you’ve got to go in and make sure that you've entered everything in the computer correctly so there are no typos, you know, you've dotted your Is and crossed your Ts.

So then you want to validate that your model projections match up with data from the real system. So you want to validate it against a known data set.

So if you look at the graph on the left, the solid line is a real system and the dotted line is a simulation. And this is a hydrograph and a simulation from a salt marsh on the Texas Coast. And you can see that in general the lines kind of matchup in terms of the patterns. So, you know, there’s some error associate with some of these curves like right in here and here they don't match up exactly but in general the patterns matchup. So it looks like it's doing an okay job of capturing the system. And, you know, this is just an example.

But then, you know, you may get to a point where they don't match up and there's an error and you need to calibrate your model.

So if you look at the graph on the right you see that there’s a big space between the solid line and the dotted line. But again in general the patterns matchup and so you might just need to fine tune some of your parameter values.

One caution though in ecology, particularly if you're looking at any kind of ecosystem process outside of hydrology, when you calibrate an ecological model or an environmental model you need to make sure that whatever you're calibrating has environmental relevance.

So as you adjust your parameters you need to make sure that that's within the range of realistic values ecologically speaking for your data set or for that particular process.

So the two last things of model evaluation, you want to determine the levels of uncertainty associated with your model forecasts.

The big kind of conglomerate term for this is called uncertainty analysis. Sensitivity analysis is also kind of grouped into this. But basically you want to figure out how good you're doing when you project a forecast into the future.

With environmental models they’re relatively complex. You know, there's a lot of uncertainty associated with them.

And you need to use some tools and techniques to kind of be able to capture that uncertainty and say we’re 95% sure this is right or we’re 50% sure and just kind of embrace the uncertainty and move forward.

And then as you’re evaluating your model this is when, as you’ve gone through sensitivity analysis and your verification calibration and validation, this is when you can identify data gaps and research needs that may not have been obvious during your conceptual model development.

So once you're model’s kind of working and running you may identify some really crucial research needs that there's a high level of uncertainty associated with, a particular value and you need to say you need to go out and gather some data to kind of refine that uncertainty.

So in practice modeling is kind of best done using an iterative approach where you conceptualize an entire system. So you draw out your whole system. And then you go develop small pieces of the model and quantify and evaluate them as you're working through the model in just small chunks. This really helps - it slows the process down a little bit in terms of mentally. It allows you to really focus in on a particular point and allows you to identify important processes and more importantly important errors that may occur within a particular piece of the model.

So for example this is an example of a forest floodplain that gets flooded at a particular time of year. So if you look on the left in the original conceptualization the model, we've got season and water depth. We know season affects water depth.

Well as we start quantifying this we say “you know what, the week of the year is actually important”. That controls the river which is what controls the water depth. And also the time of the year controls the water depth decreases. That's this part, when it gets the hot water decreases.

So here's kind of the whole system that I used as an example earlier. You can see that as you go through on the left you have a generalized diagram and on the right you have a little bit more complex diagram that identifies some processes and areas in more detail.

And for this type of model this is a box and arrow conceptual diagram where each box and arrow represents a quantification of the system.

So in a nutshell, you know, when you're developing a model you should begin by identifying the objectives for the project with stakeholders.

And in this case stakeholders can be, you know, your project development team. It's people outside if you have a big stakeholder group that's interested.

You know, if they're involved with model development that increases transparency and it increases the chance and the likelihood that they're not going to get mad at you when you're done because modeling is often viewed as a black box. By including everyone in conceptual model development from the beginning you really kind of facilitate communication and transparency.

And modeling is a dynamic process. The models are best developed iteratively where you go through each stage several times to make sure that everything is as precise as you can get it. This really facilitates, you know, again transparency and scientific defensibility. So it's an engaging process.

The more people that you have engaged in this the better off the project will be long term. So I'm going to turn it over to Christy again and she's going to finish the rest of the presentation. So thank you very much.

Christy Foran: Thanks. Next I wanted to turn to, in general, how some of these models are applied. And so I'm going to show you the results of a project that we did classifying some of the tools that are commonly used for restoration planning.

And in order to look at these tools in the context of forecasting we needed to survey models across a range of complexity. So we wanted a way to classify those tools according to their complexity. And what we did is we considered a comparison of tools based on effort it takes to apply them. And we thought about this in terms of the number of people and the number of days it would take to perform that analysis across the data that's needed and compare that to the utility, the outcome.

We define that utility is something that encompasses the relevance of the outcome. It's whether or not it gave you some uncertainty, how accurate it may or may not be, and the precision of the model as well.

And once we had this classification of models we looked at a subset of commonly used models to determine their uses and the limitations of those different sets. And then the classification helped to identify the tradeoffs that you all used in the selection of something that will give you a forecast and also for us give us an indication of what areas need to be strengthened in terms of ecological forecasting. So I'm going to show you the results of that classification.

This slide is a little overwhelming so let me spend a few minutes and walk you through it.

On the X axis here I'm showing you effort or resources that it takes to use this model. So it's just a general indication of the amount of effort that it takes to collect the data or do the analysis you need for that model. And on the Y axis here is the prescriptive utility or the precision, the uncertainty, the likelihood that that output is going to be useful for your purposes. And you'll see most of the models fall along the gradient. The more you put into them the more you get out of them. That's not surprising.

And let me just walk you through these. This is best professional judgment and it's a good example of the way this model works. This is consultation with an expert who has experience in the field. This may be very low effort in terms of the analysis of the site.

It may be a matter of how someone's visiting site or have them review historical data, give you a prescription of the function of that site.

However that person's judgment is going to be a result of their personal experience, the data or the analysis that they have available. And also different experts are going to give you different responses of course. And the same expert might give you a different response depending on how many of these projects that they've been involved with as well. So the utility of the output of that model per se may be limited as well. I wanted to make a point right here and I'll make it again at the end of this slide that this is just a generalization, of course best professional judgment in some cases is the best model that you can use for your project. And there are many cases where a professional or an expert will give you a rigorous quantitative analysis that is exactly what you need as an answer to your project.

So this circle for best professional judgment moves around this chart depending on how this model is applied. That's critical.

We're just speaking in generalities here. Here you have the evaluation procedure which is a methodology for evaluating habitat suitability indices or HSIs. These are our models that determine the quality and quantity of habitat for a specific species. They require site information be collected on site often seasonally, so that increases the effort for this model. And they're very good in terms of predictive power under some circumstances. And in other cases they have not been very predictive. And also the utilities may be limited by the fact that they're not prescriptive. They don't tell you what you need to do to fix the habitat for that species. And I will talk about this a little more on the next slide.

This one here is the rapid bio assessment procedures, the method that utilizes IBI or Indices of Biologic Integrity. It's kind of analogous in my mind to HSI. But instead of looking at specific species here you're looking at an index which determines species' riskiness. So this is suitability for individually species, this is overall ecosystem quality based on all of the bio data that's there. IBI is a very successful measure for assessing the ecosystem quality. It's been used in a number of cases and it's very useful as an assessment tool. As a predictive tool it's less useful. It's difficult to manage in a way that you get a known change in the IBI as a result of that management. And again I'll mention this again later.

This big circle is the hydro geomorphic model. This is a really interesting tool. It's a rapid assessment of wetland function. In some cases they've reported that this assessment can take only four hours. So in that case you're reducing your resource intensity way down to four hours of assessment. However that assessment is based on a regional guidebook, a big regional measurement source that you go to. And if a regional guidebook is not available then you’re increasing the resources that it takes to use this model. And furthermore that regional guidebook is not transferable from place to place so the Pennsylvania guidebook is not accessible for Ohio and vice versa. So again that may increase the resources that it takes to use that model.

And again once it's been developed and calibrated this model’s been shown to be very effective at predicting wetland function and functional capacity of a wetland. However you're not actually measuring the functional capacity of the wetland or calculating it based on a number of parameters so depending on the data that's collected and how it’s applied you can also get some error which decreases the utility of this model. And that's why this circle is so large.

Above that you see Bayesian method. This is a statistical method for analysis of the results from another model. And basically it gives you a set of prior assumptions that then you can use to develop probabilistic outcomes or future conditions. And the reason why this is so long is that these analyses are based on model outputs and available data or judgments or assumptions that then are used as the basis for these statistical calculations. So depending on the quality and the quantity of data that goes into these methods that increases both the effort it takes to use them and the utility of the output of those models.

And at the top here you have simulation models which Todd talked about. These are large computationally tested models. They require lots of data. They often require an expert to appropriately apply that model.

However in terms of quality it's the gold standard. They can prepare alternatives. You can input different scenarios. You can get prescriptive actions from them. You can get probabilistic or risk assessments out of them.

The three other components in blue on this graph -- and I'll talk about those in the next several slides -- large ecosystem models, magic bullets and model certification and again I wanted to emphasize this is a generalization.

And the way each of these tools is applied can move them around on this graph and also move your position within this large generalization.

So for example I wanted to talk about how one of these simple tools may relate to predictive or forecasting the future from this. And I wanted to use an example Habitat Suitability Index.

You're probably all familiar with HSI models. Just for an example the Gulf of Mexico Oyster the HSI Index includes among other things substrate, type and firmness, summer water salinity, historic salinity, predator abundance, disease intensity among a number of features. And you evaluate your site against each of these features and you get a score for each component.

You add those into an overall HSI score that’s between zero which is unsuitable habitat and one which is favorable habitat.

In order to do that you need site based information which is potentially seasonal or historical information and you also need a spatial analysis if you're going to sum the HSI over an area to give you overall feasibility of a project.

So those things increase the effort that you need to use this model. However the application of the model has been reported to be very good in some cases.

So for example Sturgeon management HSI can predict those populations very well and in other cases not as good.

There was a study of beaver populations that found that 83% of this HSI score did not explain population variability. So HSI explains less than 20% of the population differences between these sites.

And in terms of forecasting it's really interesting. HSI does not specifically prescribe management actions.

So for example with the oyster if you found in your analysis that historic salinity was a key factor in preventing Gulf of Mexico oyster populations from returning you would have to find a way to deal with historic salinity or some way to deal with for example, disease intensity or predator abundance.

So you would have to take the analysis from this model and use best professional judgment in order to determine how to mitigate or change that HSI. So it's not prescriptive in that way.

Here's the other extreme. This is a simulation model from the system wide water resources program. This model starts with a slope, flow, and cross section analysis of a stream. It’s supplemented with aerial photos. It adds important habitat features. It considers future conditions and future scenarios.

Then you get a multidimensional simulation with risk based biological models. So for this model you get out mathematical evaluation of each alternative relative to a reference with potential error in there and considering different scenarios.

So this is great in terms of forecasting but often time and resources and data are limited to invest in an approach like this. But it would be great if we could do it every time.

I wanted to mention large ecosystem models. They're on that graph as high effort and low utility. These are models that were developed over decades to describe the function of an entire biome. And if you look in the literature you'll find them. They’re designed to calculate flows and describe the system as it functions. But they have very little predictive value and are not appropriately used in a context for changing the function of an area from, you know, nonfunctional or low functional to higher functional. So they're not predictive of manipulation. And they're not appropriate to use in that context. So those are very interesting descriptions of how the biome functions.

Likewise we have magic bullets. And these are potential low effort tools with high prescriptive utility. This is what we’re all looking for. In general you get into the model what you put out of it. So these tools if they exist are unlikely to be reliable.

And I wanted to say as a caveat that the HGM models have often been described in these terms. It's just a matter of having the detailed guide that is utilized to give that rapid assessment. In general we need to put in enough effort to get out the critical information that we need to evaluate the project.

And finally I wanted to mention model certification. As you're all aware certified models are required for all planning activities. And model certification is a quality assurance activity. I understand that if it's managed and executed properly it doesn't increase the time for a project but it may increase the effort that's needed in order to utilize a specific model or to develop a new model.

So the quality assurance that's needed for new models as well as all quality assurance needs to be considered in terms of the resources that are going into your models and the resources that you're putting towards planning and forecasting for future conditions.

I don't want you to be overwhelmed by this slide but I wanted to include it. This is just part of a large table that is in our tech notes that's available for you by PDF. So don't strain your eyes to try to read this model. I going to talk to about a few of the blocks that are in yellow and I'll tell you what they say.

But in general in the tech notes if you look down the left-hand side are a list of all of the models that we looked at so they’re listed here by name. That's professional judgment, habitat suitability index, hydro geomorphic model, habitat evaluation procedures and so on and so on all the way down to Bayesian methods.

And again this is only part of that table. And for each of these models we describe them. We talked about their uses. We talked about some considerations or limitations of those models. And then in each case we asked three questions. And the first one is does this application or this approach estimate the probable outcome of the action? So do you get something that you can use to determine the likelihood that you're going to get the response that you want? Secondly does it predict the best outcome from a range of alternatives? And thirdly, does the method or the application estimate the current action that you need to get the future condition that you want?

And so we've evaluated these questions in general for these models, and I wanted to specifically mention three things. First of all, the Habitat Suitability Index that we've talked about a number of times does not give you prescriptive information, like I mentioned for the oysters. It may indicate to you that predator abundance is an issue, but it doesn't specifically prescribe actions to limit predator abundance. So it doesn't give you the needed current actions.

It also doesn't give you a probablistic outcome. So it doesn't tell you the confidence with which you're going to get the results that you want. But if you are comparing alternatives across a range, it may indicate the best alternative among that range by comparing those different scores to each other. So it does have strength as a predictive tool.

The same thing with IBI. This requires an index that's developed across different species to give you a richness indication or an indication of the quality of the ecosystem. And there's been a lot of effort to correlate the IBI with causes of impairment. In some cases, you can get a correlation, so one related to the other, but the strength of those correlations is different under different conditions.

And again, the efforts that have been made in the research literature for how to manage to change the IBI have been limited. So it doesn't tell you what you need to do now to get the results that you want in the future. It also doesn't give you a probabilistic outcome - doesn't give you a probability of success. But if you compare different plans, just like HSI, it may tell you which one might give you the best IBI, depending on how it's applied.

And finally I wanted to mention Bayesian methods, just because it's an interesting approach in combination with some of these others. This is again a statistical analysis of either the output of other models or available prior data or even judgment, which is formalized mathematically. And used in conjunction with these other methods, it has the potential to give you the probabilistic outcome you need. So what confidence you'll have that you'll get the outcome that you want.

It also has the potential to prescribe an action that you need to take. However, you can't necessarily look at it in terms of which alternative is better across the range, because you're making assumptions going in about the relationship for example between the size of the area that will be wetland and the expected population.

So because that's a prior assumption, it'll be a circular argument. You'll get your assumption back in the analysis.

And again the statistical methods are very interesting. They're only as good as the data that goes into them, and I think in this case it's good to be as transparent as possible about when you're making assumptions, when to use the historical data and when you're using the sort of models for Bayesian analysis.

If you'd like to review this table in detail, I mean you don't want to look at the fuzzy letters on your screen, please feel free to contact me. I've got this PDF on my desktop and I'm happy to e-mail you a copy. Otherwise it is available on the ERDC Web site as well. But I'd be happy to talk to you in person about it.

In general, we are looking at these approaches as forecasting tools across the range of complexity, and we concluded that there were some needs in terms of forecasting. The transfer of techniques and analytical methodologies of forecasting needs to be better utilized. So there are lessons there, there were limitations that have shown up in the forecasting research that are applicable) or would help planners.

And we also need more probabilistic predictive tools that can be used with limited data that are common for a lot of restoration projects. And furthermore, it'd be great to have a complete system for measuring the outcome of restoration across time and space. So a system for cumulative analysis or oversight, both for the benefit of the planning community and also for the benefit of the research community, because it's really necessary to evaluate - you may get a different response in terms of evaluation in time and space across one project or at the end of that project, compared to a region over time.

And just to bring that point home, I wanted to mention one of the consequences of restoration with regard to forecasting, there's almost a chicken-and-egg relationship between forecasting and the consequences of restoration.

Restoration includes with and without project condition. So forecasting models could provide a quantitative outcome for different actions, but then after the project, measurement of the actual outcomes are an opportunity to refine those forecasting models. So these in an ideal world feed each other to make forecasting easier, cheaper and better and also provide a coherent method for getting credit for the benefits of restoration.

And with regard to that relationship, I wanted to mention a couple of things. There's some ongoing work from the environmental benefits analysis groups, a series of tech notes, including one that I've been involved with, looking at metrics for restoration planning to try and determine the best metrics not for necessarily the specific species that the project was targeted at but the best metrics for ecosystem’s overall function that might be used to compare projects to each other and to average the benefits over a region or over time.

As well, there's some great tech notes on risk and uncertainty that look at the probabilistic forecasting from some of these tools. And furthermore, one of the benefits of developing a tool that you can rely upon for a future condition is the ability to do adaptive management. So if you can project how you anticipate your actions to change in the future, we can look in the future, refine your model -- so learn from what you've done -- and also have an automatic tipping point of when you should change the actions or the management of that site.

And we have been involved and are currently involved with some adaptive management modeling for Everglades restoration. And this work is currently under review in the peer review. There is a paper describing the overall approach, and we're actually now getting into the nitty gritty of how to apply it to a specific case, part of the Everglades.

And finally I wanted to come to our general conclusions about our research needs. You know, we understand that the potential exists for existing models to determine the uncertainty or the risk associated with the projective outcome, so we think that existing utility models can be further refined to get to a clear forecasting function. And we also think that we need to include ecosystem services as an evaluation, even in these projects that have a species-specific objective, so that we can generalize the goals of restoration across time and space.

And we hope that the outcomes, the measured final projects of those restorations, can be shared and archived and easily utilized so that we can have a system of analysis that can be used to further refine our ability to forecast in the future.

And I know this presentation has spoke to you in general terms. I would be happy to first of all get your feedback and also to provide any clarification I can. And I want to emphasize that the most exciting part of this work is to be able to bring it down to a specific project, and I'd be happy to talk to you later about any of those projects. And I'm sure Todd would as well.

Well let me stop here, and open up a little bit for discussion.

Courtney Chambers: Thank you Christy. Again please remember to take your phone off of mute if you'd like to share any thoughts or ask questions at this time. Or feel free to type your question in the chat feature, and we'll read it to the group from there. Thanks.

(Nash Nilteen): Todd this is (Nash Nilteen) in Jacksonville district. We worked with you a little bit on the Broward county water preserve area's model certification. And I guess my question is, what software did you use to make those diagrams where you had the conceptual model in those few slides?

Todd Swannack: PowerPoint.

(Nash Nilteen): Really?

Todd Swannack: Yes I have a template. If you send me an e-mail I'll send you the template.

(Nash Nilteen): Okay.

Todd Swannack: Yes.

(Nash Nilteen): Cool. They look really good.

Todd Swannack: Oh thanks.

Courtney Chambers: Any other questions today?

Jim Vearil: Yes this is Jim Vearil in Jacksonville. Question following up maybe on the adaptive management discussion. Seems to me, at least for us from Everglades adaptive management, a lot of what the literature, like Gunderson and Hollings talks about, is you have to expect surprises. We're dealing with, you know, the uncertainty of ecological systems in response. So, you know, one thing we talk about is trying to design things that are robust to deal with this.

What are you guys thinking about, in terms of research needs and how we can use this for decision support and adaptive management, making decisions? Do you all see this as an issue and a problem? Are you all thinking about ways to try to address this? I think it's going to be inherent. We have to plan for it and deal with it?

Christy Foran: That's a good question. Thanks. Yes we're working with (Andy Leshivo), and we're currently developing efforts to integrate existing modeling efforts and also monitoring data into a formalized decision framework so that we can basically check it for robustness.

So in the paper that we have submitted for review, we've done a simplified model, and this is all based on (SERDP) work for decompartmentalization and what you would expect under different rain scenarios or under different climate change scenarios, which approach or which alternative management tactic is the most robust under those different conditions?

And we've also been playing with a model - the simplified model in terms of which monitoring plans give you the most relevant information for future guidance under different rainfall conditions. So it's basically integrating the efforts that are ongoing already.

And we are looking at robustness in terms of when does the best - under this modeling approach, when does the best alternative change? How far do you have to push climate scenarios, habitat conditions or -- I'm trying to think of some of the other variables that are considered -- nutrient loading, fire scenarios, soil oxidation, that kind of thing, how far do they have to be pushed in order for you to change the most useful tactic or the most useful decision?

Jim Vearil: Okay. That's - I appreciate that. If I can maybe ask a follow-up question, if that's okay?

Christy Foran: Great with me.

Jim Vearil: All right. Building on that, you know, it seems to me in the Corps - I've been here a long time; I'm an old dinosaur. I think as I look back, I think we focus way too much on this concept of, "We're going to find the optimal solution," which I think kind of conflicts some with the idea of robustness and flexibility.

So I'm curious. You're doing this - are you all thinking of ways of how we can quantify the value of a robust plan? In my mind it could be a robust plan, maybe a little more expensive up front, but I would argue, oftentimes over the long run, if you really could measure it, it's probably cheaper in the long run because it's more able to tolerate the uncertainty and deal with that.

Is this something besides looking at? Are you all thinking about other ways to try to measure the value of it so we can assess plans and give some kind of weight to a plan that's more robust but may cost a little bit more upfront?

Christy Foran: I love questions like this because the answer is decision analysis. And what we've done with that model is we have absolutely given exactly what you said. We have given the objective for that model. Habitat restoration, cost, flood control, different species, have all been give different weights.

And the user of one of the analysis that we do, is changing the weights on that. So how much are you willing to pay for a specific habitat? How much are you willing to pay in compromise to get this benefit that you get?

So we absolutely - the model's designed specifically to do that. It's tradeoff. And the great thing about it is we can give the model or we can discuss the model with different stakeholders, and we can put in their specific opinions about the value of different parts of the model and run it again and see if the outcome - the predicted outcome is different under those different weighting conditions.

And actually I wanted to - before I let you go, let me get your name, and I will e-mail you the paper as a follow-up so that you can see what we have submitted for a peer review.

Jim Vearil: Okay. You want that now? Or at the end?

Christy Foran: It's up to you?

Jim Vearil: It's James.W.Vearil, V-E-A-R-I-L. And it's...

Christy Foran: All right.

Jim Vearil: you know, you got the rest of it.

Christy Foran: Yep yep.

Jim Vearil: And I work with (Andy), so if, you know, you have trouble, you can always send it to (Andy) and tell him to send it to me.

Christy Foran: Perfect.

Jim Vearil: Thank you.

Christy Foran: Yes great. Thank you.

Max Millstein: One last quick question. Can you give an example of the Bayesian type statistical model and maybe a magic bullet? Like I guess just from a real project? I'm having a hard time...

Christy Foran: Well I can't give you an example of a magic bullet. I can tell you what has been said about the (HGM) is that if you have a reference guide, a regional guide, that in four hours you can do an assessment of a wetland that is going to characterize its function over different - then you can play with that assessment, you know, put it in different conditions and see how it potentially can change.

So, you know, wouldn't that be wonderful within a few hours to get an accurate output that is going to be predictive of different conditions? So the thing is how well it works in your specific case and whether the data that you have is representative of what's happening at the site. And there's other caveats. So I'm guessing that in general magic bullets don't exist. It's - a magic bullet would be a tool that takes very little effort to use that gives you exactly what you need. If you find them, please send them my way. That would be great. But as long as I know we're not making the easy button yet, you know, when we get to that point we'll definitely send it out to everybody.

Max Millstein: Okay fine. And so you had in mind maybe some sort of a quick enduring model that made a lot of assumptions to produce a result?

Christy Foran: I think - no is a simple answer. Although I think that the tools that exist now, with enough data over time and space, you could do an analysis to say how well does it predict the outcome? What may or may not happen if you change this? If you do some activity, how does the output change?

So basically kind of like Todd was talking about, with the sensitivity analysis. What - if you change one parameter, how does the output change? And that kind of analysis would get you closer to a magic bullet, but you'd have to have a lot of cooperation and a lot of data to do the analysis.

But I think it's a good research effort, and it's one of the conclusions that we have is that, you know, if we look at the existing tools and how they're used, can we do some big meta analysis that makes those tools more prescriptive?

And then I'm not sure if I answered your question but if I did, can you remind me of the second question?

Max Millstein: I guess a Bayesian method?

Christy Foran: Oh. Let me think. So Bayes rule - like - off the top of my head I'm not going to be able to give you a good example of a Bayesian method, but Bayes rule gives you the probability of an event, given what you know about another event. So this is the probability of A, given B. And there's a mathematical equation that base determine where - basically saying if you know about B and the relationship between B and A, then the condition of B, knowing that B exists, gives you a probabilistic assessment of whether or not A is going to happen. And it's all based on that rule.

So you're looking at a set of data, you're making assumptions about the relationship of that data to what you hope will happen. And based on that assumption, you can get a probabilistic outcome. So the analysis is only as good as the data or the assumptions that you're using and the relationships that support them.

And then it's a statistical process that gets you a number with 90% confidence you can expect the habitat to reach some level or the population to reach some level. So the output is exactly what you want, in terms of forecasting and in terms of model certainty. So it's a great methodology, but it's an analysis of existing data. It's based - it's only as good as the foundation. Does that help?

Max Millstein: Yes yes. I guess if you can think of an example, just send that around maybe.

Christy Foran: Yes I absolutely can. Can I get your name as well?

Max Millstein: Sure. It's Max, M-A-X, .J.Millstein, M-I-L-L-S-T-E-I-N, @usace.

Christy Foran: Okay.

Courtney Chambers: Okay. Hey Christy we've got a couple questions in our chat feature over here.

Christy Foran: Okay.

Courtney Chambers: One of them said - from Rock Island said, "Currently working at incorporating ecosystem goods and services into tool development, and prior slide was - (MCDA) was listed as one of the most time and date-intensive methods. How do you reconcile creating indices for ecosystem services into a shorter planning window?"

Christy Foran: I work a lot in the field of (MCDA) so my experience may be different than what's noted here. And in really simple terms, (MCDA) is how everyone graded the reports that they had in school. So, you know, 10 points was for the introduction and 50 points was for the body of the material, and 10 point selling and it added up to 100 points. That's (MCDA).

Basically it's taking different components that you're interested in, giving them a weight in terms of the total score, and doing an analysis for each one. How good was the introduction? You're either grading it against a ruler or a set of measurements that have been evaluated (in literature).

So I've seen (MCDA)s, for example grading a report, that are very quick and very limited in terms of their intensity. An (MCDA) like that, a grading the report example, the benefits of that (MCDA), although it's very simple and it may not be very rigorous or robust, then why is the introduction worth only 10 points as opposed to 15? Is there, you know, questions that you would have to answer in terms of an actual restoration project.

But the benefit of it at that very simple level is two-fold. Number one it's absolutely transparent. It's - what you're doing is there on paper, you've graded the introduction out of ten points, and here's what you've given it and why.

And the other thing is that it makes the process more repeatable. So the next person that grades the next report only gives the introduction up to 10 points. So in confines the space for evaluation and the rules for evaluation so that it's transparent and repeatable. So even at a very simple level there are some benefits to (MCDA).

In terms of being time and data intensive, you know, yes as well to that. So you can do - like we are doing - applying this (MCDA) to the Florida Everglades, we've got a quantitative decision model that incorporates ecosystem models that have been developed over the Everglades for decades and incorporates years and years of data into probabilistic assumptions and it assesses those assumptions across different scenarios for climate and rain and population levels and that kind of thing. So yes as well. So (MCDA) in itself is just a way to specify different measures you're going to look at and add them all up into a comparison.

So let's see if I answered the questions. "(MCDA) is listed as a time and data-intensive method." And it - in and of itself it's not. It can be used just like grading the report.

"So how do you reconcile creating indices for ecosystem service into a shorter planning window?" I think (MCDA), like other indices, it's just a matter of the available data, what's going to be the most predictive or relevant to the information needs, and limiting, you know, really thinking about the information needs for the project first and limiting the decision to those critical pieces of information. I hope that answered the question.

Courtney Chambers: All right thanks (Nell). Before we get too much past our time, let's answer this last question in the chat feature, and then further questions that you may still have, please e-mail Todd or Christy to get answers on those, and I'm sure they'll be happy to follow up with you.

But this last question here was from Mark Mansfield, in NAO. Working in the Chesapeake Bay Watershed, he's curious to see how TMDLs can be facilitated for public policy decision levels, given the federal/state differences of extent of federal involvement. And then he has a separate question on sea level rise and (MCDA).

Mark Mansfield: Yes this is Mark. I can take that offline, because that's one of a (one each). But...

Courtney Chambers: Okay.

Christy Foran: Yes I'd love to talk to you Mark. And let me just say that there's been some published work on (MCDA) and looking at different stakeholder groups, specifically EPA versus the Corps of Engineers and how (MCDA) can be used for - in that case it was dredge material placement in New York and New Jersey Harbor.

And it was kind of a neat study in that in the end, you know, EPA and the Corps of Engineers had completely different priorities, but they ended up agreeing on the top three alternatives based on this (MCDA). So I can point you to that project as well as talk to you offline about this.

Mark Mansfield: Thank you so much. I appreciate it. That's what I was looking for.

Christy Foran: Great.

Courtney Chambers: Excellent. Thank you all for your participation in our discussion. And again I'm sure they'd be happy to talk with you more about specific examples if we didn't get to your question today.

Thank you Todd and Christy for sharing your great presentation.

END