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Julie Marcy Hello everyone, I am Julie Marcy, a research biologist at the ERDC Environmental Lab and your webinar host today. I am glad you are able to join us for the Restoration Webinar on leveraging existing data to improve fish movement and passage analysis. The program today is by Drs Andy Goodwin and Dave Smith of the ERDC Environmental Lab. We are going to continue to share these ecosystem restoration webinars with you and as always, we welcome your topic ideas if something comes to mind.

I will talk more about this in detail later, but you might want to make a note on your calendar that our next learning exchange webinar will be on the 30th of November. Just a few notations before we begin the presentation today. We are recording this session as usual and will be posting it on the Environmental Gateway website where we archive the presentations. I see that (Andrea Carpenter) Memphis has been nice enough to use the chat feature to tell us who her participants are. If the rest of you would please do that, at least give us what district/division/office you are calling in from and the number of folks calling in with you (if there are more than just yourself), that helps us track the participants and their location. So, if you could take a minute to do that, that would be very helpful for us.

As usual, we will save about the last 15 minutes of the presentation for questions and answers, but we are very informal. If at any time you hear a term that's unfamiliar to you or that you need a little more information on, please stop David and (Andy) and ask the question verbally, or you can use the chat feature to ask a question during the presentation so that we can make sure that everyone comprehends the information being presented. If you are using a speakerphone for a group, remember to keep it on mute when you are listening and obviously you will need to unmute it when you are ready to speak to us. It is very helpful to use that mute feature particularly if you are in a noisy area or have some background noise occurring. Something new, if you haven't already done so, remember to signup for our webinar announcements at the learning exchange. I have the website noted here. This is our new notification procedure. Instead of getting the regular e-mails that have the large PDFs of the PowerPoints attached and Bios, we are going to be using this new learning exchange notification system so that the files will actually reside on one of our ERDC servers and not clutter up your inboxes. Only folks who have signed up for the service will receive it. We took the existing list for the webinars and put that into the original exchange list, but if you didn't receive a learning exchange note in addition to the regular e-mail for this particular program, you want to be sure and go to that website and signup to make certain that you do receive the future announcements. From now on, we will just be using the learning exchange and not the typical e-mail notifications. I think you will like the learning exchange better because it also enables you to put an outlook calendar notice automatically in your computer if you desire.

So, let's get back to today's topic. As I mentioned, our topic is going to be on leveraging existing data to improve fish movement and passage analysis. Our speakers are Dr. (Andy Goodwin), Research Environmental Engineer, and Dr.

Dave Smith, Research Ecologist, and both gentlemen are with the ERDC Environmental Lab. Gentlemen, I am going to turn the program over to you.

(Andy Goodwin): Well, I want to thank everybody for taking time out of their busy schedule. You have to bear with me, this is my first webinar. And so, it's a little bit different than of course sitting up in front of everybody and being able to see people's body language. Please do send questions either via the chat or interrupt me if something isn't clear. And with that said, our talk indeed today is going to be leveraging existing data to improve fish movement and passage analysis using an approach that we refer to as the ELAM approach. And my colleague Dave Smith is also here on the phone. And I ask Dave to jump in if you think I have missed anything. This is truly a collaborate effort that involves a number of people both within ERDC Environmental Lab, with districts, divisions, and academia and consulting firms. So, even though it's just Dave and I here on this presentation I wouldn't want to give the impression we have - just the two of us - accomplished all this ourselves. It's truly a multidisciplinary approach, if you will.

The problem issue, why bother with yet another tool. What I would say is the overall thrust and purpose of what we are doing is that there are a number of tools out there which address fish passage, fish movement. And we are not so much looking at planning tools that are adequate in their existing from, but there are a number of cases out there, a number of situations, and contexts where existing tools are just not sufficient. And I think we will touch a little bit later on why it is that fish are not just inanimate objects that respond to whatever in a very predictable fashion. Sometimes they can do very unpredictable things, a lot like humans and other animals. And we have been trying to dive into some of that literature to get a better, more robust handle on why fish do very complex things.

At a broad level, if one was to look at fish movement and habitat analysis and forecasting, typically over the last many years, you started off with some suite of hydraulic or water quality variables. And then there is some sort of correlation that yield some description of where to find fish, and what fish are responding to. What many folks may not know is that, generally, the theoretical assumptions that underpin this approach are that each individual fish has perfect knowledge of the global environment, they do not experience a change in internal state, and they exhibit an all-or-nothing choice.

What we know from emerging research on fish and decision making of individuals across taxa is that you really need a more flexible approach, one that acknowledges that information is limited due to varying sensory acuity and past experience of individuals, there is of course a change in internal state (whether it's physiology or learning) that's important to understand their behavior, decisions (all else being equal) are sometimes very irregular and there are partial preferences in individual decision making (which can manifest themselves to the population level), and there’s continuous behavior adjustment in response to these factors.

Our approach to coming up with a solution for how to tackle these complexities is to integrate available data resources in a way that can allow a higher fidelity approach to fish movement and passage, and in habitat analyses. Our way that we do that is this ELAM approach, an Eulerian-Lagrangian-Agent Method. And, if you were to look at a generic system and an aquatic system, for instance, this is how Eulerian and Lagrangian and agent frameworks break down. Typically, with any generic system you can discretize it into a mesh, whether 2D or 3D, and that mesh would be used to capture phenomena that are small in time and space scale. It would be used to govern the physical, hydraulic, water quality, terrestrial, and/or avian domains and it's simply a mesh composed of nodes…and it's used by GIS and virtually all hydraulic and water quality models. We then integrate into that a Lagrangian framework, which you can see as a continuous trajectory used to capture phenomena that are large and/or rare in time and space scale, which we use to govern sensory perception and the movement trajectories of individuals. All it is is a continuous directional trajectory composed of discreet locations.

Lastly, what I think our contribution to the science has been (because Eulerian and Lagrangian Methods (ELMs) have been around for several decades, at least), is that we found a way to inject this agent framework into ELMs, hence the ELAM or ELAM framework. This agent framework is used to capture phenomena where internal state are important; it governs cognitive / memory domains responsible for the behavior decisions of individuals in its mathematics of animal perception for handling stimuli sensory processing, internal state, memory, responsive behavior, and other dominants and facets of psychology.

By integrating these into a single, cohesive framework we were able to describe fish movement and behavior at large scales; for instance, the upper left there is the scale of an entire river reach; at more refined scales, let's say a scale of woody debris or a couple occurrences of woody debris. But then, we can also really dive down to a very high detailed level, if and when it's appropriate. The data affords to really, and I guess in many ways you kind of, get “inside” the mind of the individual to understand what are the robust processes going on. And what we have found is that we can put this framework to application such as engineered construction, for instance; habitat as well as engineered structures; for instance, dams. Now, there are multiple components obviously that are necessary for this framework to be relevant and germane. And one is, I think, where a lot of folks (you know, hydraulic modeling) where we wanted to layout here that it (hydraulic modeling or water quality modeling) is readily doable.

The needed basic data exist for almost all aquatic systems in the United States. Why do I say that? Well, most systems (of course, not all) have some sort of slope, flow, and/or cross sectional data. And, of course, it can take many forms, for instance: HEC-RAS input, or it could be work done by a graduate student or an undergraduate student at a local college or university. And, my colleague (Dave Smith) has been working on a package that can readily use this type of simple and readily available data to constitute the needed inputs for generating a hydraulic model, and his package incorporates the elements of not only the simple data but (using the imagery of Google Earth) we can supplement the transects with information from aerial photos, for instance, from Google Earth or Google Maps. We can draw up a multidimensional environment, whether 2D or 3D, and then we can actually add in habitat features (even if they are not precise); they could be general representations of what we can see through Google Earth imagery.

And, I think we will come back to how and why there‘s value of this data, and why it's not overkill. Hydraulic models probably, as many people can see, provide just a tremendous amount of information. And ,what we have found is that the insight given by the information from a hydraulic model is truly valuable, even if you didn't have the perfect conditions going in to setup your hydraulic model. At the very least, you can glean from a hydraulic model many of the same quantitative and numerical information that you would need for a lot of planning models; for instance, HSI curves or IFIM…and I will kind of defer to my colleague (Dave) on that as he knows a lot more about that than I do. But wanted to layout that there’s tremendous information that one can glean once the hydraulic model is in hand. And, the current state-of-theart is that these are actually readily deployable for small rivers as well as large rivers.

Now, coming back to maybe the kernel of this presentation and, that is, animal decision-making behavior. Why is it important? Why can't we just do simple stimuli response or simple correlations? Well, a lot of people (at least when I am presenting in person this kind of talk) talk a lot about this, but it is indeed true that fish (and of course it can be species and context dependent) do have the capacity that in some cognitive tasks they have shown to have a complexity and a sophistication that's on par with non-human primates.

Now, where does one begin when tackling such dynamics? Well, kind of surveying the literature with regard to robust phenomena across taxa what we find is that most biological systems adapt to different conditions and environments. The nervous system has mechanisms that use prior experience to predict future events. These mechanisms can, and they do potentially support, behavioral prediction in a wide range of taxa and are just not in the more advanced or the larger taxa as we typically think. And, there is still a lot of emerging research with regard to, well, what are the specific mechanisms used…and here I just pulled out a survey of recent research where they have found, for instance, that it's just the timing of information as it's received by an individual that can impact how an animal makes a certain decision and you can get the same information but, depending on the time order of sequencing with which it arrives, the animal might do different things. So right there information is not only insufficient, [we need to know] how did it arrive and what's the time order? They have found that in animals, for instance birds, actually have the ability to plan in advance or at least that's some of the current thinking and hypotheses.

What we have found is that cross taxa (again, there is just a sophistication that was maybe not truly appreciated and acknowledged…but has made it into some of the more popular publications in the nation: for instance, there was an issue last year on Animal Minds in National Geographic) our approach to taking this information and modeling individual and group behavior in complex environments is to identify and capture robust phenomena regarding how individuals detect and respond to environmental changes. What we are hoping for is a concise (I would say, theoretically-realistic) algorithm replicating fundamental and pervasive behavioral phenomena. And, the idea is that the payoff would be a common model applicable to many fish species and contexts, whether it's passage, movement, habitat restoration, etc. In fact, we are using this approach in non-ecology settings, for instance, to look at the movement behaviors of military scenarios. So this is an approach that I think is diverse and robust, that it extends far beyond a fish…maybe even to non-human animals and into the human realm. But we will stick to the animals in this presentation.

Julie Marcy: Andy, this is Julie, I am going to interrupt you just a second; I'm hearing some background voices.

(Andy Goodwin): Yeah, hold on. Let me take care of that.

Julie Marcy: Okay. I was going to say either use the mute or ask folks to talk a little quite or if you can use mute.

(Andy Goodwin): All right.

Julie Marcy: All right. Did you threaten them sufficiently? …oh, very good.

(Andy Goodwin): Sorry about that.

Julie Marcy: No problem.

(Andy Goodwin): Like I say, a cubicle environment sometimes it's unpredictable.

Julie Marcy: We have to be flexible.

(Andy Goodwin): This next slide is basically just to show that there are equations behind these concepts. So I am trying to keep this at a level where it's not overwhelming, but there are algorithms (mathematical equations) that go with many and each of these concepts as well as the integration of these concepts; that is, equations from how does one track acclimatization to a stimulus, and that have to deal with this time sequencing that I talked about.

Looking at perception as opposed to what you might measure with a probe, what we found across taxa were that animals often don't respond to the intensity of information as you would measure it, for instance, with a probe. In many contexts what animals are responding to (including humans) is the relative difference between what you would measure with a probe and what the individual is acclimatized to. And, if you think about yourself, when you walk into a new room or a new environment often your perception and the way you think of the room in terms being too bright or too cold is often in reference to what you are acclimatized to and what your present state is. So what we have found in our work, and we will get to this, is that you just can't look at what’s the information and then the response. There is a relative difference that is important and, of course, then that requires that you track it.

Laying out would these relative differences exceed thresholds, and even when you exceed a threshold you might not respond right away. And, there are researchers that have focused on this element; the behavior called “response latency". And then, of course, you can rank things in terms of probabilities and then weighted probabilities that lead to a behavioral repertoire. By testing the approach (when I show two examples: one at a detailed scale and one at a broad scale) with regard to the detailed test, of course, the fair question comes up why Pacific Northwest fish passage. Well, I should say first and foremost that this approach is not specific to fish passage, but test data has to come from somewhere and we happened to cut our teeth with regard to this data earlier than a lot of the other data sets.

What is unique and what I think is of value to the data (again in the Pacific Northwest) is depending on how you look at it, arguably it's the toughest test of the approach. That is, can you model fish in a way that when you release them a kilometer or more upstream in a river can you get those modeled fish to pass in a meter size, or sometimes sub-meter size, openings at a dam and in three dimensions in the correct proportions as they were measured in the field. And we will show the results of that test. What has really been, I think, of value, (this is putting in a plug for being a member of the Corps of Engineers) is that the Corps of Engineers here in the Pacific Northwest really sits on a tremendous amount of biological data that arguably exceeds what the rest of the world has, combined. And, so that really is a unique opportunity for the Corps of Engineers to lead this area of research and applications. And here (kind of the last bullet is where I am talking about terms of the Corps' opportunity) is that sharpened knowledge of the approach for applications where inevitably we move to systems or scant data I think is where we have a moment in time to learn and to train a model to develop knowledge. We have to keep in mind that the reality is most systems where this technology would go there can be very, very little data. And this approach will have limited value if we can't find a way to work with those types of systems.

The common problem here in the Pacific Northwest is how to make design decisions that fish accept. Fish accept or reject a structure based on a variety of perceived stimuli and stressors and (before my time) researchers, dozens and dozens of researchers had done the correlation approach where they have looked at everything from velocity fields to acceleration fields…all sorts of different physicochemical and social stimuli to say, okay, when these conditions exist how is a fish passing the dam…under these operations, what can we say. And there have been some insights into the building blocks of behavior, but I also think it's fair to say that there has never really been a cohesive hypothesis put forward in terms of how do fish act at a broad scale. Of course this is a model (i.e., a simplified level), but how do they encrypt information to make a decision that can correspond with what was observed in the field? And I think we have been able to do that. A population of discrete particles or individual agents each make unique decisions and they each have a unique trajectory and what they do is they use the sensory ovoid that we provide them to acquire information stored within this computational mesh.

Kind of skipping over a lot of details (but, I think that's appropriate for this presentation at least and until the Q&A session) is how well does it work? I mean, inevitably that's the end of the question. Well, I am going to be showing some results that we have had in hand for awhile. We are looking here at five projects here in the Pacific Northwest and we have data from a number of different dams and different years at each dam and different structural and operational configurations for each dam. So there is a lot of diversity as far as the regional picture as well as there is a lot of diversity in terms of data for even a given dam; we have fish passage data for more than just a few conditions. In summary, you can kind of split the slide down the middle; on the left hand side, what we have done is show a graphic of what [modeled] fish look like as they are released about a kilometer upstream. They move towards the dam and you can see here in this little black plot with colored lines that fish do different things as they get closer to the dam…and two fish arriving at the same position in front of the dam will likely do very different things because they got there via two different pathways. So, therefore, their history, their acclimatization are different and so they perceive the same environment differently because their history is different. Have a plot on the lower left; on the Y-axis is virtual passage as predicted by the model and then the X-axis is observed passage as collected by a variety of different monitoring technologies. You see generally three colors and that represents three routes of primary interest: you have the bypass, which is the typical focus of these monitoring efforts. The black is the powerhouse or the turbines along with any in-gallery passage. Black varies per site but, generally speaking, that’s how to describe the black: that it’s powerhouse. And the blue is the spillway. You can see on the right hand side what we get turning the rules off in the model. And, what you get is passive particles, or particle tracking. And this is used quite extensively and has been for some time; it's pretty common to do in a hydraulic model. But you see that the agreement (the correspondence between virtual passage and the observed passage) drops off appreciably. There are a variety of different ways in which one can summarize this data. There is just, I mean, there is not even two…there is at least a handful or several handfuls of ways to summarize this statistically. From some of the responses that I have we have worked on developing these. I will just call it a kind of a custom metric that ranges between zero and one. And you can see with the rules on (between zero and one) we are at about 0.77. With the rules off, passive particles was about 0.42. So you can see there is value in adding these rules…this approach in order to describe what fish are doing.

Kind of diving down just a little bit deeper here to the bottom, you can see what passive particles look like and with a lot of hydropower dams you can't just have random or Brownian motion because there is a substantial flow and if you look at those passive particles and you say, well, what happens if fish just move randomly (because you can implement that in the model) what you see is that these lines (the passive particle lines) would generally go to the same place, they'd just be wonky. Whereas in the upper two plots you can see ([aside:] first and foremost you need each sub-plot: the left is a top down view, the right of each sub-plot is a three dimensional view, and the bottom right sub-plot is a side view) here on the general upper left you have what a real fish did; it was an acoustically-tagged juvenile salmon. And, then the upper right is a virtual fish…and you can see both differ appreciably from passive particles.

We can dive into what virtual fish are doing (does it correspond with what actual fish did as well as look at the population scale metrics); kind of dive down even a little bit further. And then, we will bring it back up. We can actually go down and we can query the model, either as we are trying to achieve correspondence with an acoustically-tagged fish or after we already have correspondence. And again that's if acoustically-tagged data is available and here, in this situation, it did. Once we have some correspondence (modeled fish are able to replicate what fish were doing in the real world, which is very different than passive particles), we could say, well, what was the virtual fish doing. And here, in the right hand side we are able to gain some insight into what the virtual fish were experiencing and the decisions that they were making. And what you find is that sometimes things go on and behavior emerges that makes a lot of sense once you see it, but looking down as an observer can sometimes be difficult to see in a short amount of time.

I have this slide here largely just to provide you a web reference if you want to go and look at additional imagery and videos that we have of modeled fish versus acoustically-tagged fish. But to kind of just put out this question (which is very important and often tends to be sponsor-specific): is the model accuracy sufficient to forecast future alternative scenarios. So kind of leaving that to the side, we will tackle this second application: a test from the Southeastern US. This is in contrast (and an example that we want to show) to show that you can advance system knowledge with simple data. And, that is, maybe all you really need is fish data from netting, if those are the resources that one has, and water quality and hydraulic patterns may only be available at broad scales. This type of data is sufficient, and we have known it to be sufficient for some applications. To look at, for instance, the operational impact on fish over many miles and months, and with a specific example I'm about to show, the question is: can modeled fish released near the beginning of the year and with a hydraulic and water quality model: can it [the model] resemble distributions as measured by some folks in a boat with nets measured many months later.

We are continually trying to drive the model and its applications down to the point where we hope that we can drive this model using data that may not be that much greater than the data that was used to initially identify and observe the problem in the first place…because sometimes that will be the limitations. Looking here, this is the second example we are going to be looking at fish movement. This is blueback herring in J. Strom Thurmond Lake on the border between Georgia and South Carolina, and there were questions with regard to how does the operation of Richard B. Russell Dam impact the movement of blueback herring in JST Lake. Again, 60 kilometers long, what we have found is that temperature, dissolved oxygen, and flow could be used to describe their movement up and down the lake as well as vertically.

We simply had a CE-QUAL-W2 (laterally-averaged) model, which provides much less resolution than a 3D CFD model, but it can also provide information over a much larger spatial and temporal domain…at least with current resources; those obviously are always changing. What we have found is that we are able to achieve correspondence between the model (in which virtual blueback herring responding to temperature, dissolved oxygen, and flow gradients) with what was observed in the field…again folks in a boat measuring through gillnets and mobile hydroacoustics. And, you can see here that if you look at (longitudinally you can collapse the lake into a single depth distribution) we are able to get an r-square of 0.93. And if you collapse all depths and then we are able to describe where a fish were and were not up and down the reservoir. We are able to do that with an r-square of about 0.67. This model was dynamic with the dissolved oxygen and the temperature; they're updated every couple of minutes in W2 and the model ran from February (when we released our fish) but the netting was actually done in the model literally using a virtual boat and a virtual net. And what sounds fancy, but was not that hard to do, was then we compared our virtual netting with netting that was done in the real world in August of that year, 1996.

There are obviously limitations with any model; it's always an abstraction of reality…and we know that. Where those triangles are you see on the left hand side, the blue triangles represent incoming tributaries and that's where a laterally-averaged model is not going to be as strong; there is also a red triangle, which indicates a major differencing in the reservoir. With all of those locations your velocities are not going to be as strong as in other areas. What we found is that surveys in those areas are where our model performed weakest and that explains a lot of where the model's off from what was observed from a boat. Similarly, I just wanted to put this web address out in case you wanted to actually look here at this web site: side-by-side, passive particles and our model behavior. And again, the same question is posed: if you're a sponsor, is accuracy sufficient to forecast "what if" future alternatives. Turning back to these applications, as well as others, our observations of this approach is that we can often begin tackling fish behavior analyses within literally just a couple of hours after the arrival of hydraulic or water quality data…and that has been very important to our team…and, that is, we know resources are limited, they are becoming more limited. So we have to have fast turnaround. In our (a lot of) our non-government sponsors, for instance public utility districts that fund our work unit in the northwest, turnaround time and on-time, on-budget elements of our work are very important. So we've worked really, really hard (very hard!) to get the turnaround time down.

There have been a number of cases where we have actually been provided the hydraulic and water quality model before the biological data was available. And, that is, folks are out in the field…they are collecting the biological data; they are also collecting what were the river conditions and the dam operations. But when they pulled their gear (while the hydraulic information in terms of river conditions and dam operations are readily summarized for hydraulic modeling, for instance), a lot of the biological data (whether it's mobile hydroacoustics, fixed-location hydroacoustics, radio- or acoustic-tag telemetry) can often take weeks or months to summarize…and in the meantime we have had a number of cases where we have been asked to run the Eulerian model on the hydraulic data. But, the biological data wasn't in; sometimes our sponsor had it, but we did not, and sometimes nobody had it. We have actually run the model, given the data back to our sponsor, and then they made the first comparison…and we have had probably half a dozen of those situations…and the model's have actually performed quite well, I would say…between (on average) 10 to 20 percent or within 10 to 20 percent of what was observed in the field. And the important caveat there is that the biological data for a lot of these datasets (just the biological data itself) was plus or minus 10 percent of what was thought to be the actual value. The approach we've found has worked at least with the tested east and west coast species…again trying to emphasize it's just not Pacific Northwest fish passage where we have cut our teeth. It has worked, the tool's approach, I am sorry [I meant to say]…the tool has worked across years of observation and at different sites and scales.

Merging capability that we have going on right now we are looking at the movement of sturgeon on the Mississippi and, as we have done in the Pacific Northwest, we have tried to understand the movement of sturgeon under the existing configuration…and, if we can do that well enough, to then ask the question: well, how would fish respond to different alternatives in fish passage. And, making up a virtual reality version of an idea of a fish passage alternative is very easy, relatively speaking, in hydraulic modeling and then this ELAM model would go on top of that and try and give an idea of how would fish respond to that. As we have seen in the Pacific Northwest, it's often not as straightforward as though they will do this [or that]. This is kind of tying back to some of the cognitive dynamics that fish possess; it doesn't always make prediction an easy thing to do.

This [slide] is work that largely my colleague, Dave, has been trying to lead up and that is with regard to stream and river restoration. Again, we are often dealing with systems and questions where there is not a lot of data; how can we use the SHAPE tool that I talked about earlier to take the readily available data (Google Earth, Google Maps, and other things) to makeup conceptual designs, whether 2D or 3D, and to incorporate into that elements of habitat structure and other complexity using tools and methods that, again, my colleague, Dave, has been developing. He developed hydraulic output, here in 3D, but it doesn't necessarily have to be; it can be 2D. And then, we run this ELAM fish movement model. And then what we can do is we can actually feed into existing Corps of Engineers' planning models…with HSI curves or other approaches and which (whether through path complexity or residence time or time of year and which fish enter or leave the system) there are a variety of ways in which the fish movement can be summarized and then feed a higher level planning model.

One important thing that we have found has come up is that sometimes there are resource limitations to dive into behavior a little bit more than what's currently available as just the cost of implementing a telemetry system is too much for many reasons. We have been working on developing this cognitive ecology research flume in order to rapidly deploy behavior analysis for a variety of different species of fish. This is a fully climate controlled facility so we could do all sorts of fish. This facility is planned to be located in Vicksburg [Mississippi] but we can do a variety of species that you never find in Vicksburg. And the idea is in this flume we could test behavior in order to develop algorithms of fish movement when, for instance, acoustic-tag or other types of telemetry is just not in the cards.

So, in summary (this is my second-to-last slide), when is this Eulerian-Lagrangian-agent method important? When…if you have important (what we would argue) things where the movement behavior of highly mobile individuals influences engineering design success. And, there are a couple of situations when we are implementing an engineering design but we have animals who can readily move on their own. So we are not talking about systems where the water is moving so fast that they [fish] are going to go with the flow [no matter what]; we’re talking about flow scenarios where a fish doesn’t want to go in and they can easily do such. Now, we have to understand their decision making process. And, of course, this work is already been focused on those cases where existing methods are proving insufficient. What is an ELAM in our view: it's the integration of all three reference frameworks. These are the only three reference frameworks that exist in physics. We brought them together to scale time and space so that each process is optimally simulated, transform information and achieve maximum fidelity, and (we are essentially trying) to relate environmental pattern to animal movement behavior response, which is actually needed when (maybe) the ultimate question is actually just contaminant exposure. Well, how does one assess alternative perturbations in environmental pattern to different engineering designs? That's what this ELAM framework (at a broad scale) is meant to address. Again, here's a summary of what is Eulerian and Lagrangian and agent here. This framework describes dynamics as Eulerian. Perception and movement trajectories are Lagrangian. The decision making process is categorized as our agent framework…and it's just kind of a conceptual way to simplify the mathematics.

And maybe I'm right on time. I think I had 45 minutes. It's 11:44 at least on my computer and this is the last slide. And just to emphasize: the idea being that this can fit within an adaptive management strategy where as model accuracy improves so does the quality of engineering guidance as it's hypothesis limited. But, as we move forward in the biological hypothesis development and improve it, so is simulated behavior and so is decision support for the next cycle. And with that Dave and I would (speaking for Dave) I think we would be happy to entertain any questions, comments, and criticisms.

Julie Marcy: (Andy) and (Dave) this is Julie, could you talk a little more about some of the sponsors or customers you worked with on this and maybe some of the questions they were trying to answer specifically?

Andy: Yeah, we had a number of sponsors, most recently our sponsors have actually been non-federal, non-Corps; non-federal have been public utility districts which have historically been very hesitant to engage in collaborative work with the federal sector…given that they regulate them. And we have been able to overcome that and tackle some of the questions of the public utility districts with regard to fish passage, engineering design guidance…and the way that they view it [the ELAM model] is there are basically three tools; so there is hydraulic and water quality modeling (which has been around for a while, at least for the last decade); there has also been biological field monitoring; and, in their view at least (this is what they have articulated to me is), they view us as kind of a third tool…and the reason why I bring it up is the tool is (that is, it is a tool that's an abstraction of reality, but it is) meant to really advance the state-of-understanding of what animals and fish are doing. So when it's applied in context with those other two tools (and the public utility districts have been funding us under this for very specific projects that are tight deadlines and tight budgets), they have probably been our biggest sponsors the last five years. Before that, there was a lot of Corps of Engineers' District investment. It was also project driven out of Portland District and Walla Walla. Most recently, our work has been picked up again on a project basis by Portland District and Seattle District, where there are very specific questions in terms of what do fish do if the structure is changed, what if the operations are changed. So, I guess, in summary, I would say that most of this work has been driven by projects and project schedules and budgets and probably had a mix of maybe 50% over the last 10 years of Corps' support and public utility districts' support.

Julie Marcy: All right, thank you (Andy); either of you or (Dave); we have a couple of questions in chat if you will see the first one that is from (Dan Walcott).

Andy: Dave, you and I had talked a little bit about this earlier; did you want to answer (Dan's) question?

Dave: Yeah, I'm going to. The way that we have been addressing that so far has been, for example, in addition to work in the northwest we have been doing work for the Sacramento District and the Sacramento District has got a planning model called their “standard system methodology”, which is going through the certification process. I don’t know exactly where it's at in that process. It’s basically an HSI curve driven type model. So we are integrating with that certification process; it’s that we are basically helping them collect data in the river and then we are developing an ELAM of conditions which we’re interested in and we are going to pull (we are going to basically parse the simulation results into) new HSI curves that you will be able to trace the pedigree back to actual data collected in the river. So the strategy is to default to the HSI curves that are being used in the planning model, so the actual form itself is it's really a method; last one is really a model so that makes sense.

Julie Marcy: And then there is an additional question from (Tom) unless (Dan) needed any additional clarification?

Andy: I think I will punt to (Dave) on (Tom’s) question too because I think (Dave) has been working a little bit more on that area of large navigable rivers with, I'm assuming, the Mississippi?

Dave: Yeah, that's - hi (Tom) - so we, in addition to work in Sacramento, we have also got some great support from Rock Island and St. Louis Districts on the Mississippi River and looking at developing an ELAM there to kind of help with moving fish around. And, initially, the work has really been focused on how the fish is responding to features near the dam, but we have been able to model many kilometers; in some cases, of the river itself. And, that model we have got a lot of features, including all the wing dams and back flow areas and side channels…and what's kind of interesting that comes out of the work that’s just as important is to have in there (because like Andy had illustrated earlier) is the time sequencing of information in fish. You can move fish up but will they occupy the river in some ways important to how they actually reach the dam and approach the dam and maybe even pass certain parts of the dam. And so, yes, we have examples that are in development; at those locations we have prototypes that we can share with you and, I think, it looks really promising even though one of the real challenges is that the data that's available to vet the ELAM in these locations is much less, and also probably much more difficult to collect, than anything you got frequently in the northwest. So we have been using the types of data they have got, which is often times as catch or net surveys; it could be distant surveys in some cases, it's hydroacoustic surveys and making rough comparisons to the model with an effort to kind of broaden out those applicability areas. And, results we have been importing, a lot of these results now, into ArcGIS. So the [ELAM] model runs kick out an Arc type data file that you then look at using Arc itself to do the comparisons between your observed data and the model output to assess whether you have got good correspondence or not. Does that cover your question?

Julie Marcy: Remember if you are on mute you will need to unmute for us to be able to hear you.

Man: That's fine for now, thank you.

Julie Marcy: Are there any additional questions for either (Andy) or (Dave)? Well, you will have this PowerPoint and the archive recording available for access that you can look back through at your leisure. If you think of some additional questions that come to mind I'm sure that (Andy) or (Dave) would be happy to answer a phone call or email that you might send to them. Gentlemen, thank you very much for sharing the status of your work and knowledge with us today. Also. I thank all of you who took time out of your schedules to participate with us today. This will conclude our webinar for today, but please make a note on your calendars that our next session is going to be on the 30th November and (Jon Hendrickson) of the St. Paul District is going to be talking about the use of two-dimensional hydraulic models and ecosystem restoration planning on the upper Mississippi River. So (Dave) and (Andy) touched on some upper applications today and we are going to continue with that and related topics on the 30th. (Andy) and (Dave) thank you again for sharing your expertise with us. That concludes today's session.