US ARMY CORP OF ENGINEERS

Moderator: Courtney Chambers
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Courtney Chambers: Okay at this time I'll give you today's speaker on prioritizing fish passage improvement. Kyle McKay is a Research Civil Engineer with the US Army Engineer Research and Development Center Environmental Lab as I mentioned earlier. Since joining ERDC in 2007 Kyle's research has focused broadly on examining ecological effects and infrastructure projects. Some of his research projects have addressed quantifying environmental benefits of ecosystem restoration, fish passage improvement, environmental flow management, vegetation flow interaction and the effects of woody vegetation on levee integrity. From August 2011 to August 2012 Kyle participated in the US Army Corps of Engineers long-term training program at the University of Georgia Odum School of Ecology where his doctoral research focuses on managing freshwater for ecological objectives. He is stationed in Athens, Georgia to facilitate cooperative research between ERDC, the University of Georgia and the Environmental Protection Agency Ecosystem Restoration Research Division.

Additional information about Kyle can be found in his bio posted on the Learning Exchange along with a PowerPoint and the archive of today's meeting. And I'll post a link to that site at the end of the meeting in the chat feature for you to copy and paste or save somewhere.

Kyle we're very happy to have you with us today. At this time I'm going to give you the presenter rights and we can begin.

Kyle McKay: Okay thank you Courtney. I'd like to first start by thanking Courtney and Julie Marcy for all the organization they put into these this Webinar series. And I'd like to think everyone for attending today. I know time is short and people have plenty to do so thanks for making sometime today.

Today I'm going to talk to you about two topics related to fish passage improvement and some of the ongoing research projects that we've got addressing this topic. And let's see, in general I'm going to go over four topics the first of which is the broader issue of hydrological connectivity of which a subset is fish passage. Secondly what alternatives exist to improve fish passage and how can we catalog and organize those? Secondly how do we compare alternatives of a single barrier? Usually by assessing some sort of fish passage rate. And third how do we evaluate the cumulative effects of multiple barriers on the landscape from the perspective of overall watershed connectivity?

So starting with the first of those, I really like this definition from Cathy Pringle of University of Georgia who says that hydrologic connectivity is a water mediated transfer of matter, energy, and/or organisms within or between elements of the hydrologic cycle. And we often conceptualize connectivity relative to organisms like fish or migratory bird fly ways. But in reality there is a much larger suite of issues that could be addressed here such as connectivity of rivers for delivery of carbon or large woody debris or movement of sediment or in the lower left you see the carbon delivery of the Amazon River to the Western Atlantic Ocean.

And with each of these different processes there are multiple dimensions of connectivity. And usually we think of these in terms of longitudinally along river channels, towards the mouth and the estuary, laterally between for instance river and floodplains, or vertically for instance between a pelagic and a benthic zone or a benthic and a (hyporheic) zone. And then each of those can vary in time. So this is a multidimensional problem. And we're just focusing on one particular issue today. And that's longitudinal connectivity for fish movement.

On top of this issue of connectivity, we've systematically disconnected our watersheds in the US whether it be historic mill bins all across the Eastern US or levies that disconnect that river floodplain interaction or roads which can serve as fish passage barriers or even connectivity as it relates or is interrupted by something like thermal power where changes in temperature may disrupt movement of a particular organism.

So again today I'm focusing in on one particular connectivity issue and that's fish passage.

So in this first section I'm going to talk about some of the things we're doing to help identify what alternatives could improve fish passage.

And we've split these and I'm using the royal "we". This is Jock Conyngham and Craig Fischenich's work. And I'm just kind of briefing you on it today. But they split it between two big topics, the first being heavily improved passage in the upstream direction. And generally you see these categories of alternatives emerge, things like technical structures or traditional Denil Fishways or high head or low head dams. You're starting to see some more natural templates emerge so issues like natural bypasses or rock ramps. A third general class of alternatives are operational strategies whether it be spilling more water over spillway or the example of trap and truck fishes so catching them below the dam and driving them around to the other side and dumping them off. And then there's some odds and ends categories that aren't as well defined in terms of those three categories things like movement for non-fish species like eel or lamprey. And then of course I failed to mention the obvious alternative of barrier removal in the case of many small structures that emerges as a pretty powerful alternative.

So and then secondly how do we adjust downstream movement of fishes? So after we've got them upstream (dag gummit) fish want to move downstream too.

So how do we do things like install physical barriers to prevent entrainment in water uptakes or diversion or structural guidance systems that rely on things like pass racks or their bubble curtains that have been used or sound and light disturbances to direct fish in a particular to a particular part of the river that may provide more safe passage.

So and then how does one select among those alternatives? There are a lot of different considerations a come to mind. But the first general category is what are we designing for? What ecological (record)? Are we designing for a particular species or age class of that species or a guild for instance salmonids or strong swimmers or migratory fishes?

We may design something very different than if we were designing for resident fishes like the small benthic fishes in the southeast like the beautiful darters and chubs we have down here.

Again the ecological design requirements could vary in terms of time of the year in terms of life history needs or swimming capabilities or where they rest in the water column.

The needs of a sturgeon and a shad are quite different or they could be. Because sturgeon are benthic fishes and shad are largely pelagic. So there's the ecological dimension.

And then there's some more practical issues of things like site or design elements such as what are the - what's the hydrograph in the area? What's the discharge or the flow regime and how does that influence the efficacy of a particular passage structure? And does a particular site have constraints relative to its lateral or longitudinal dimensions? So do you have a finite amount of space in which to install for instance a bypass or a ladder?

And at that particular site there may be some issues of channel dynamism. There are many places in the US where rivers are highly dynamic systems. And so designing appropriate to the particular sediment regime and flow regime for your site can be absolutely critical.

And then again there we have kind of a catchall of some other things that come to mind that's really important. I mentioned transport of sediment but there's also movement of large woody debris or ice if you live somewhere north of Georgia.

And often we want to rely on local and regional expertise for these sorts of design and construction of maintenance issues because they're familiar with the topics that tend to emerge. For instance I wouldn't know as much about movement of ice around a particular fish passage structure given my experience in the Southeast.

So what (Jock) and (Craig) have done is they've condensed a lot of this really amazing information into a shorter document. So there's lots of guidance out there on fish passage design but often these design documents and guidance documents tend to be hundreds or in some cases thousands of pages.

And what (Jock) and (Craig) were after was coming up with that Reader's Digest version dwindling things down to the general categories of alternatives when given a fish passage project and how would one compare those strengths and weaknesses? So they've written up a short document on this topic. And it is working its way through our internal review process at ERDC and we hope that that will be coming out relatively soon.

Now transitioning a little now that we've discussed different options for design alternatives, how do we compare those alternatives and assess passages?

I'm going to start with kind of the petty issue of what is a fish passage rate? Depending on who's assessing it it might be assessed very differently. So one could look at passage rates in terms of an individual organism or the number of attempts at getting over a barrier, a single fish swimming up how times does it attempt to pass before it actually passes?

You could also assess passage rates in terms of a population scale which I think is probably the most common way of assessing passage which is of a given species or age structure within that, what percentage of fish are making it past a given structure?

And then third what portion of the species is successfully passing would be a third way of identifying a passage rate.

In general I'm going to use this term in the broadest sense. And I will often refer to passage rates as efficiency measures or pass ability. And I'm going to define them as a proportion of fish passing a structure scale from zero to 1. So zero to 100% whether it be for an individual, for a population or for a community.

So it would be wonderful to be able to provide a table that had passage rates for every species that might be of interest and every structure types. So for instance you would just use a lookup. Say I'm working with Gulf sturgeon and Denil ladders or Gulf sturgeon and lock grants and there would be a range of passage rates there. Unfortunately those data are scattered or often unavailable and in many cases just don't exist.

And on top of that there's the complexity that these passage rates can vary at a single structure. So in a high flow year where there is simply more water going into a bypass there may be higher success of passage than in a low flow year where there's less depth for a given fish to work with.

And then the third complexity would be that passage rates are not collected comprehensively for these multiple structure types.

And then finally we often don't assess passage rates for the non-game or non-migratory species. Most of the data that exists on passage are relative to long-distance migrators like (unintelligible) and sturgeon and shad and things like that where those little benthic fish I mentioned earlier often aren't even assessed relative to passage efficiencies of the structure.

So although we'd love to give you that lookup table, instead what we're going to focus on is different ways of assessing it and demonstrating how these methods can apply to a particular case and looking at a menu of options for assessing passage rates.

And generally speaking these methods can be classified into two general categories the first being an empirical or data-driven view that's often associated with monitoring at a particular structure. So one goes out and does something like mark recapture, collects mark recapture data for a particular population or conducts fish surveys above and below a structure. And you can look at the efficacy of a passage around that structure.

Alternatively there's the analytical view of the world which is also used for forecasting project benefits or predicting passage rates. And often these come in terms of hydraulic rules as they relate to swimming speed. So the Forest Service has a standalone software called Fish Crossing that compiles a number of data sources for fish swimming speeds relative to hydraulic parameters like velocity and depth.

Also in that category is the really exciting work that (Dave Smith) and (Andy Goodwin) have done with individual-based modeling what they call ELAM or (Elarium Lagrangian) agent-based model where they have individuals that make different swimming decisions in a specific flow field.

And then a third option relative to analytical or predicting style method are expert judgment. These are pretty common in terms of giving the experts for a particular region that know their species of fish and their swimming capabilities and giving a range of estimates for what they think passage might be.

So what we're focused on in this part of the project is compiling these methods in sort of this menu of option and discussing some of the complexity of how to choose a particular method for a particular project and application.

And as part of that we're conducting some examples or some demonstration projects across a variety of methods and sites and species. And some of these were already underway. For instance the last one there was lock and dam number one on the Cape Fear River.

(Frank Albertson)'s group at Wilmington District has been doing a lot of work in terms of assessing passage along with North Carolina State University.

But we're also developing some new case studies looking at things like filter streams in the Mississippi and passage around low head weirs or floodgates in Missouri and then finally the effect of recreational features on passage rates.

There's a recent recreational feature installed in Missoula, Montana. And there's very little information right now on how recreational features could potentially create high velocity flow that would reduce pass ability. So we're looking at that site as well.

So moving on to the third phase of this talk in terms of barrier prioritization, we're interested in what is the cumulative effect of multiple barriers in a watershed.

So taken - given this hypothetical watershed one could go through and given a limited budget which barrier should we improve or remove? And you can make a very logical argument that we would want to improve the one with the lowest pass ability or the one with 10%. But that's also the one with the least amount of habitat upstream.

And you could also make the argument that we would want to improve the barriers that's lowest in the watershed or the most downstream only. That's also the one with the highest existing passage rate.

So what we're working on in this part of the project is developing methods for incorporating passage rates and habitat quantity and quality assessments to come up with overall estimates of connectivity in a particular watershed.

So to take a brief tangent here every gardener or any homeowner knows that there's a difference between when you've got - you had a tree pruned or when someone came out and cut it.

And we know that conceptually this is also true of disconnecting watersheds with barriers. However in watersheds we don't have good methods for when we prune the tree versus when we cut it down.

And so that's really what we're trying to do in this part of the project is determine when a tree remains disconnected such that it's pruned and remains viable and alive and supporting a healthy fish community versus when it's cut and when it's no longer producing that fish community. And fortunate for us unlike a tree, a watershed can be reconnected. And so we can effectively regrow the watershed.

So when we started this project we didn't know of any connectivity metrics for assessing these cumulative effects. So we began developing one that works off of the notion of cumulative passage rates.

So here you have a hypothetical watershed with two dams. And you can imagine that if 50% of the fish pass the first barrier, Barrier A and 40% pass the second barrier, cumulatively above that second barrier, only 20% of the fish can make it above there or .5 times .4.

You can also layer on to this the amount of habitat that's upstream of those particular barriers. So if we multiply the amount of habitat by that cumulative passage rate we have a notion of acceptable habitat.

And our metric which is the habitat connectivity index for upstream passage -- and that's a mouthful -- we use the ratio of accessible to total habitat so in this case it's 6 over 15 or .4. And then what that allows us to do is play out different games in terms of restoration and look at different alternatives. So we can do things like assess the no action alternatives relative to removing one individual barrier or removing both barriers.

And then...

Courtney Chambers: Kyle just one moment. As a reminder we're getting some background noise. If you wouldn't mind please put your - double check that your phone is on mute. Thanks.

Kyle McKay: So although this is a conceptually simple algorithm when you have a watershed with hundreds of miles of habitat and potentially dozens of barriers the mathematics get really tricky.

So what we have done is reframed it as a graph theory problem. And that way we can take advantage of existing mathematics in the field of network analysis. And this just helps us keep track of the bookkeeping side of things. So we can rewrite this where in the lower-left you see what's called an adjacency matrix. And that just summarizes the shape of the watershed.

And then we can assign passage rates for each node in the watershed and quantities of habitat for each of those nodes, the quantities of habitat that are upstream.

So that's just a way of formalizing the problem and as a network. And of course we're not the first people to use networks in any sort of ecological application. People have been doing this for decades spanning all the way back from (Ray Lindeman)'s work in system dynamics in the 40s.

So this is a highly or well-studied field that had amazing applications across things like disease transfers, spatial networks, behavioral networks, as well as feed webs. So in our case instead of energy moving through atrophic system we're looking at fish moving through a watershed. And a number of folks have done this with watershed work as well. And we've all kind of been working in parallel. And then recently a bunch of papers started coming out and now folks are making these connections and we're starting to work together with these folks.

But everyone takes a slightly different view of the world. And so the point of this slide is that network analysis is proving to be a very powerful tool for this sort of assessment. And that these techniques allow us to assess the cumulative effects of these structures and the spatial condition of them.

So we can move beyond scoring and ranking systems where we're only looking at barriers in isolation and then effectively ranking which one is the worst and fixing them one after the other. This way we can look at it more systematically.

So for instance we've worked with the Cherokee River and the Fish Passage Improvement Project that's been going on there. There are actually many barriers in this watershed, well over 30. But we focused on nine barriers that we deemed actionable. And we developed two to four alternatives at each site so always the no action alternatives but then also things like installation of bypasses or removal of some structures or retrofitting of intake structures -- things like that.

And we had a panel of local experts who graciously estimated passage rates for each location and structure which was quite the feet. And that allowed us to parameterize this model and ask what actions should be taken to get the most bang for our buck.

And here I'll present some of the data towards the (unintelligible) trout but in reality we assess connectivity relative to eight different species.

So just to give you a feel for how different some of these structures are, they vary in height from being not spanning the channel at all to being off channel or oblique structures all the way to being 30-foot, 35-foot tall massive concrete dams. And they - some of them were withdrawing water, some were not. So they're very different. But our experts that were estimating passage rates allowed us to compare these different structures.

So for those nine barriers that we looked at and two to four alternatives each, if you look at every permutation of those actions there's over 1000 potential watershed scale restorations plans. And we assessed all of them, combinations or all the permutations and identified the cost-effective alternatives.

And using this information of course you can make a decision using a lot of different logic, for instance whether you are maximizing the benefits or have a ceiling of cost available for a particular project or you're looking at a threshold and benefit relative to cost so large increments and benefits or small increments and costs. But this information could be used in lots of different ways when making those decisions.

In addition to estimating those passage rates the experts provided not only their expected passage rate but we also had them estimate the worst case and the best case scenario. And then that allows us to look at the uncertainty associated with those estimates.

And what this chart shows it is our connectivity index, the uncertainty in our connectivity index for each of the cost effective plans.

And you can see that in some cases it's quite uncertain but if we for instance take all of the worst case estimates and all of the best case estimates we can book end our analyses and ask ourselves things like are we making the same decisions regardless of which estimate of passage? And we can have confidence in our decision.

We've also been using these connectivity indices in a more hypothetical context. So we created an algorithm that generates watersheds of random shapes and then distributes dams randomly in those watersheds. And we can change the numbers of dams that are distributed as well as the passage rate of each structure. And we can start to look for these general trends in connectivity. So in these hypothetical simulations we use watersheds of 50 miles of habitat.

And you can see that beyond a certain threshold around ten dams, the connectivity is very, very low. But the difference in ten dams and 20 dams becomes effectively very small because the watershed's been disconnected. But again these are general trends that you can use these types of connectivity indices to look at.

And now while we're doing this, extending this work right now we've started what I've described here is only focused on upstream passage. But now we're working to assess downstream passage as well as coupled upstream and downstream passage. So you can prioritize relative upstream movement, downstream movement or total movement. And we're developing those indices now and we're also developing a model to import watersheds from for instance the national hydrography dataset and port streamlines and dams from something like the National Inventory of Dams. And the user would specify passage rates. And then under the hood it would compute these connectivity indices.

We've - after developing our model we're going to develop some novel applications to demonstrate how the model could be used to account for things like seasonality and passage rates multiple species as well as uncertainty estimates and other complicating factors.

At this point our project has these three papers that we've been working on. We've got some others we're developing.

But if you're interested the Truckee River work can be downloaded from this link here the first link. The second bullet is the Reader's Digest version I referred to earlier.

And the third bullet is a paper that summarizes the Truckee River application as well as the application for general trends and connectivity. And that was just released last week so we're pretty excited about that and I'm happy to share.

And then before I open the floor for questions I'd like to just reiterate that there - that hydrologic connectivity is a much bigger issue than just fish passage. But fish passage is a really interesting application of connectivity.

Secondly that we're working on this reader digest of passage alternatives to provide a quick reference rather than the detailed guidance document that exists other places.

Third estimating passage rates can be tricky business. So we're trying to provide what options exists as well as examples of how those get applied in the real world.

And then finally the barrier prioritization model we're working on should be available in the next 12 to 18 months and we're excited to get your all's feedback on that as well.

So with that I will thank my co-authors (Jock Conyngham) and (Craig Fischenich) and open the floor for questions.

Courtney Chambers: Great thank you Kyle. Just a reminder if you're going to ask a question over the phone line remember to take your phone off of mute so we can hear you or feel free to utilize the chat feature and send that question to everyone if you don't mind.

Man: I have a question.

Courtney Chambers: Yes sir. Go ahead.

Man: Has anybody developed a simple tool of integrating fish swim speeds, burst speeds prolonged? I mean it would kind to be a simplified ELAM type model?

Kyle McKay: That's - that sounds similar to the Forest Service tool Fish Crossing which provides relationships between hydraulic parameters and burst speed and swim speeds So that might be a good place to start but it - does that address your question?

Man: Yes. Thank you.

Courtney Chambers: Other questions?

Man: What have they learned at the Lock and Dam 1 Cape Fear River?

Kyle McKay: Well I'm am hesitant to weigh in with (Frankie Albertson) on the phone because he knows much more than about that than I do. But they've been designing around not only fish locking but also installation of a rock ramp and how fish are moving through both of those structures.

(Frankie Albertson): This is (Frankie Albertson). I can comment if you'd like.

Kyle McKay: By all means.

(Frankie Albertson): The stretcher is completed. We completed our first spring season of monitoring those are mostly interested in passing of (agenous) fish such as American shad and striped bass.

We have two endangered species of sturgeon in the harbor but since they're endangered they're kind of rare. We can't get enough to really tell what they're doing.

But the first season monitoring we had about 50% of the American shad that approach the damn passed but only about 21% of striped bass.

We're going - we've had contract with NC State University and Dr. (Joe Hightower). They're going to monitor also this spring and see what the passage rate is.

If it's consistently low we had a goal of 80% passage of those species. If it's consistently low we're looking at methods that we can to tweak passage. But we're disappointed in the fairly low passage rates. But we're also understanding even though there's been about 40 of these constructed nationwide we're the first ones to scientifically monitor the passages so that's where we are.

Man: Thank you.

Courtney Chambers: Thank you for that comment and follow-up. We have a question here in the chat feature from (Conrad).

He asked would you generally characterize your efforts at this point as continued literature review or a meta-analysis?

Kyle McKay: I would say that under the first issue of assessing fish passage alternatives that was largely a literature-based issue.

The second topic of assessing passage rates were compiling literature and doing some literature review but also collecting some new field data and providing some case studies or demonstrations.

And then the third topic of assessing or prioritizing barriers I'd say that it's neither. I would say that it's new work but the algorithms are being developed by our team.

Courtney Chambers: Thanks Kyle. There's another question here. Are you aware of any tools that consider passage of invasives such as Asian carp relative to native fishes? How can this be quantified?

Kyle McKay: So I think that's a very important issue is the positive and negative effects of connectivity whether it be invasive species or for instance disease spread or maintaining separate populations to avoid hybridization.

But the same general tools would apply in terms of assessing passage rates and connectivity. The only difference being you're trying to make connectivity and passage go to zero instead of one. So it's the opposite direction of effective but the same tools apply.

Courtney Chambers: Very good. Thanks Kyle. Any other questions?

(Sean Milligan): This is (Sean Milligan) in Walla Walla. Just relative to the first guy's question about fish swimming capabilities, there's a couple of guys out in the West that have developed fish energetic models primarily for (Sumwadits) and bull trout.

But I think any, if you know some of the swimming characteristics of a specific species they can input it into the model. But it uses it - those models combine fish swimming characteristics with hydraulic characteristics to determine when the fishes energy is depleted and relative to passage.

(Pat Powers) in Washington state and (Mike Lovett) in California each develop different energetics models.

Courtney Chambers: Thank you for that. Any other questions today?

As you're thinking I'm going to send the link to the environment gateway where we post the archived meetings and the PowerPoints in the biographies of each of our speakers.

And along with today's meeting you can see the archived files from all of our Webinars and the - since we've begun this series. So it's a valuable resource that you can access at any point in time. We provided the recorded version of the meetings and the transcripts that go with those.

One more opportunity here for questions if you have any.

All right well thank you for sharing with us today Kyle and thank you participants for joining us.

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