

Evaluating the Effectiveness of Seasonally Assisted Migration through Fish Rescue Programs

John Ossanna: I'd like to welcome everyone from the US Fish and Wildlife Services National Conservation Training Center here in Shepherdstown, West Virginia. My name is John Ossanna. I'd like to welcome you to our series held in partnership with the US Geological Survey's National Climate Change and Wildlife Science Center.

Today's webinar is titled, "Update on Evaluating the Effectiveness of Seasonally Assisted Migration through Fish Rescue Programs." We're excited to have Jonathan Armstrong and Brittany Beebe with us today who are from Oregon State University. To start things off, please join me in welcoming Abby Lynch who's with NCCWSC, who'll be introducing our speaker today. Abby?

Abby Lynch: Thank you. Again, I'm Abby Lynch. I'm a research fish biologist with the National Climate Adaptation Science Center. It's my pleasure to introduce our speakers today.

First, we have Dr. Jonathan B. Armstrong. Johnny has a BA in biology from Lewis & Clark College and a PhD from the University of Washington. He was a Smith Fellow post-doc at the University of Wyoming and has recently joined the faculty at Oregon State University in the Department of Fisheries and Wildlife.

Much of Armstrong's research explores how animals cope with seasonal variation and habitat conditions, and how human land use affects their ability to respond to environmental variation. The project that Johnny and Brittany are going to be presenting on today is funded through this work.

Brittany A. Beebe is our second speaker. Brittany is a Master's student in Armstrong's lab. She is working on evaluating seasonally assisted fish migration. She has a BS in environmental science and a minor in eco-hydrology from the University of Nevada, Reno. She previously worked as a research assistant in the aquatic ecosystems analysis laboratory at the University of Nevada, Reno.

Thank you both for joining. We look forward to hearing your presentation.

John: Johnny, the floor is yours.

Dr. Jonathan B. Armstrong: Thanks so much for having us. Thanks for the intro. Thanks a lot, everybody, for tuning in.

I'm going to be talking about fish rescue today. I want to, first, just acknowledge our collaborators at WDFW, Kale Bentley, and Thomas Buehrens, our co-PIs on this project. Another collaborator that we get a lot of help with, with lifecycle modeling is Russ Perry at the Cook Lab for USGS.

The motivation for this project is captured in this picture right here. It's that ecological drought and climate warming are creating scenes like this where we have streams drying up. Often, these streams have threatened or endangered fishes in them.

It puts managers in a really tough spot. They watch these streams fragment. They often see fish in isolated pools. They're faced with the decision to do something or to watch those fish die.

It's a tough spot, especially when there's ESA-listed fish because as anyone who has ever tried to apply for a NOAA scientific take permit knows, we take mortality of ESA-listed fish really seriously. The question is what should folks do.

One technique that's quietly emerging as a climate adaptation strategy is fish rescue, in which you move fish out of these habitats before they dry up. That's what we're going to be talking about today.

I just want to spread a quick outline for the talk. We're going to first introduce the history and widespread use of fish rescue. Then focus on how it's being applied as a climate change adaptation tool and think about fish rescue in the context of ecological drought in the flow regimes of rivers.

Then we're going to focus on a specific fish rescue program which has emerged in the Pacific Northwest. We're evaluating this program. We're going to talk about how we co-developed an approach for evaluating the assumptions and potential costs and benefits of this program.

Then we're going to close by introducing our methods and the science products that we're creating as a part of this project.

If anyone by chance happened to Google fish rescue, you may have come across a very different type of fish rescue. When I started looking into fish rescue, I put it into Google.

I found out that there is a type of fish rescue out there that's apparently better known than the type that we're going to be talking about today, where if you have an unwanted koi that your grandma got you, you can give it away to a fish adoption agency.

Today, what we're going to be talking about is the second page of Google search items, which is the type of fish rescue that you may know by what it's also called, which is fish salvage.

In this type of fish rescue, basically, if there's some sort of water withdrawal or stream drying that's anticipated, people will go out and they will capture fish from the habitat that they anticipate will go dry. They'll capture them and they will move them either to captivity or to a habitat that's not anticipated to go dry.

Here's an example of people in an irrigation canal in New Zealand capturing one of these native eels. As I mentioned earlier, this is sort of an emerging tool in climate change adaptation.

However, one of the things I was surprised as I started to do more research on it is that outside of this field, it's actually a ubiquitous and surprisingly non-controversial technique. As I just referenced, it occurs globally. It happens throughout the US, New Zealand, the UK, and other areas. It's actually a really common part of in-stream work.

This means construction in rivers, with things related to irrigation infrastructure or hydropower. For example, if you look at examples from Oregon, if you look on the ODOT website, the Department of Transportation or the City of Portland, you'll find references to fish rescue or fish salvage.

If you start digging around, one of the key things you'll notice is that the methods and the costs associated with this technique are incredibly variable. It can be everything from a grassroots effort to something with helicopters and consulting firms that cost hundreds of thousands of dollars. The methods can be really variable. We'll get into this in more detail.

One of the things that's neat about fish rescue is that it's often a way to engage citizens and stakeholders. Often, it is a grassroots effort where passionate anglers go out and try to save fish that would otherwise die.

Here's a couple examples. In New Jersey, folks go out from Muskies Incorporated. Their slogan is "Home of the Muskellunge." They go out and they save muskies that would otherwise be faced with stream drying.

Trout Unlimited in Canada does fish rescue to save fish from water withdrawals. There hasn't been a lot of research done on fish salvage and fish rescue, but there was one review on the topic of fish stranding and intervention by Nagrodski and others.

One of the key things that they found is our understanding of fish stranding and our implementation of fish rescue has really been dominated by fish rescue and salvage pertaining to human activities.

They found that over 80 percent of the studies documented were related to human activities and 60 percent of those related to hydropower. Specifically, when you have hydropower operations that do large ramping of flows to meet power demands, this is the sort of thing that can create real serious stranding issues.

Much less is known about the role of fish rescue and response to natural stranding and stream drying.

Just as a couple examples of rescue and response to human activities, some of you might remember the Oroville Dam crisis in 2017, when this massive reservoir on the Feather River nearly collapsed. While they were repairing the spillway, fish were stranded and had to be rescued. That's one example.

An example here in Oregon where we are, related to human activity, is that every fall, on the Deschutes River below Wickiup Reservoir, the flows on the Deschutes gets severely drawn down in order to fill up this reservoir. As a result, fish can be stranded. Here there's a grassroots effort where people go out and they scoop up these fish.

Many of them are trophy brown trout and native redband trout, which people care a lot about, so they go out and they scoop up these fish and move them to areas where they're less likely to become fragmented. There has been a limited amount of evaluation of fish rescue and salvage efforts.

One of the few formal analyses that we could find, it had a pretty negative evaluation of the economic feasibility of rescue. However, Higgins and Bradford suggested that there's about a 10:1 cost to benefit ratio of fish rescue.

I think something to keep in mind here is the results are really context dependent. In this case, this is an example from Canada of salvaging fish for hydropower.

Here, they were accessing remote sites by helicopter, which clearly does not sound cheap. Most of the fish they were rescuing were juveniles that were then released back into the wild. You can imagine most, especially with salmonids, most juveniles are going to die anyways.

If you're rescuing a bunch of them, you're probably not getting a lot of bang on your buck if you're releasing them back into the wild. You can imagine, if you're rescuing adults, or rearing those rescued individuals in captivity, and if you're doing it with volunteer effort, these results could probably change a lot.

Now I want to focus our background to thinking about fish rescue, not in the context of in-stream work or these very explicitly human activities, but think about it in the context of ecological drought and climate change.

Here's an example of where we work in Southwest Washington and a stream that goes dry in the summer and is reduced to fragmented pools, such as the one pictured at the left.

As background, I think a key point to make is that fish stranding and fragmentation and drying is not something that's unique to arid regions or regions with Mediterranean climates. It's something that is really ubiquitous.

For example, I was just in Cordova in Alaska this March. I saw several dry streams there, even in one of the wettest places that I've ever been in North America.

Also, here's a picture below from Southwest Alaska, where I've done a lot of work on juvenile coho salmon. Here, even during the wet season, we see a lot of fish get stranded in ephemeral flood plain habitats after flood plains are inundated. We see fish getting stranded and fragmented there.

What is unique to areas with certain climates is the extent and severity of this fragmentation and drying. To provide some contrast, here is some climate data for Vancouver, Washington, area where we work, and for Dillingham, Alaska, which is where I worked previously on coho salmon in Southwest Alaska.

What you can see is, one has a Mediterranean climate where the summers are much dryer than the rest of the year and coincide with the warmest part of the year. Whereas in Dillingham, there's less seasonal variation of precipitation, and the warm summer is actually the wet season.

One of the consequences of this is probably that if you're a fish and you get fragmented in Alaska, you just got to wait until the next rain, which isn't going to be very long. If you're a fish in one of these more Mediterranean climates and you find yourself stranded in a fragmented pool, you might have to wait several months.

The implications for fragmentation and stranding on fish mortality and on the rearing capacity of streams are much more severe in these more arid or Mediterranean climates.

Even within these climates, there's a lot of variation in the timing and the duration of the low flow events and of fragmentation and drying. I provided these two results. These are some USGS staged data that I found online.

These are two watersheds. The East Fork Lewis River, which is our focal system, but also the Carmel River, where there's also fish rescue efforts.

I just want to show that even within these two systems where there's pretty severe drying at parts of the year, there's really large differences in the seasonal timing and duration of these drying periods. There's variation even within a single climate type.

As streams get into these low flow periods, especially streams that are dominated by rainfall, they can start to fragment. Here's a nice depiction of fragmentation by some of Stephanie Carlson's Lab's recent work out of UC Berkeley. You can see here the classic wet/dry mapping.

You can see it here as the season progresses through the summer. You go from this continuous ribbon of habitat, where the pools are shown as black dots, to this increasingly fragmented habitat where, by the end of the summer, this stream is dominated by either isolated pools or entire reaches of dry channel.

Here's a picture of Brittany Beebe in one of our focal tributaries. You can see we had the same conditions of drying in Washington as I spoke to seeing in California. Here's one of our fragmented pools.

To some degree, much of this stream drying is natural, but I think what a lot of folks, probably many folks on the line right now are concerned about, is how increasing human demands for water and how changing climate could potentially exacerbate stream drying and increase its severity and extent.

This is not an issue that's unique to the Pacific Northwest. For example, just last week in "The New York Times," there was a feature on the Rio Grande River and how a combination of changing climate conditions and intense water demands is causing more and more of this river to dry up.

The Fish & Wildlife Service is rescuing endangered...I printed there to try to reduce mortality in the face of stream drying. As more and more managers are dealing with species of concern or populations of concern in drying systems, a really intuitive and common shared response is, "Well, let's try to rescue these fish and prevent these major mortality events from drying."

This is not an exhaustive list, but here's some examples of the type of rescue efforts that are going on in the Pacific states and in no particular order.

The first one is the one with the images pictured here, the Scott River, which is one of the major tributaries of the Klamath. During the severe California drought in 2013, the main stream river got so low that adult returning fish could not reach the tributaries where they spawned and spawned in the main stem.

In response, the state and other folks transported the emergent fry from those spawning into tributary habitats. A longer term effort is that of folks in the Carmel River. I know one of the people involved with this project, Kevin, is on the phone. Kevin, thanks for your email earlier.

On the Carmel, they have had a 25-year effort that's captured over 400,000 juvenile steelhead from drying reaches and either move them to reaches that weren't drying or to captivity.

There is a recent empirical evaluation of this program published in "Plos One." Another example from the Klamath is on the lower portion of the river in McGarvey Creek. It's a tributary that's real close to the ocean. The Yurok Tribe is rescuing fish.

One of the neat intersections of multiple conservation tools here is that one of the things that they're going to start exploring is whether beaver dam analogs which can increase flow permanence whether they might be a conservation tool for creating drought refugia that they can use as the destination for these rescued fish.

Lastly, we're going to be shifting gears now in describing a pretty major fish rescue effort program that emerged in the '90s in the Pacific Northwest, that's Northwest Wild Fish Rescue.

This is another example of one of these grassroots programs. This program is run by Dave Brown who's just a passionate local citizen, who saw his streams drying up and the fish that he cared about dying.

He started this program where they began rescuing fish. Like I was saying, he's an example of just a concerned citizen. I'm pretty sure he's a leather salesman, so he's not a scientist. It's just an example of someone who's passionate and wanted to do something about the fish they cared about.

It's volunteer run. They certainly incur costs, but it's a smaller budget compared to a state hatchery or something like that. It operates on small tributaries of the Salmon Creek and the East Fork Lewis River which flow into the Lower Columbia. I'll show a map in just a second.

Most of the fish that are rescued in this program are ESA-listed, juvenile coho salmon that are part of the Lower Columbia ESU. They're collected under a 4D Permit from NOAA.

These tributaries, they drain the foothills of the West Slope of the Cascades. They have these rain-dominated hydrologies. Stream drying and fragmentation occurs annually.

We don't have great long-term data on water quantity in these tributaries. If you talk to locals or state bios who've worked there, they suggest that it's gotten worse in recent decades, probably because of suburban sprawl and more wells being drilled and factors like that. Basically, increasing human water demands.

Here's a map of where this rescue occurs. If you look in the inset, you can see that this is in Southwest Washington. These are tributaries that drain into the Columbia on the left side of your screen. This is part of the Columbia where it takes that sharp bend around Portland.

This is the bend in the river that caused the Willamette Valley to be formed in the Missoula floods, but that's a whole different story.

You can see Salmon Creek and the East Fork Lewis River and all these little tributaries. These are these streams that dry up where the program works. You might be thinking, "OK, these are small rain-dominated streams in areas with pretty heavy land use.

"Why make these the focus of your effort? Why not focus on protecting more pristine habitat that might have a snow-dominated hydrology that might just be a better habitat for these fish?" Part of the reason is that some of the major habitats in this ESU that are snow-dominated are now cut off by flood control dams, places like the Cowlitz River.

These tributaries actually represent some of the best remaining habitat, especially for the East Fork Lewis population. They have this nice low gradient habitat that historically was some of the best habitat for coho salmon in this region.

As I mentioned earlier, here is what these habitats look like in the summer. Here's a picture of Brittany crawling over a cottonwood and what used to be a deep pool. You can see there's reaches that go entirely dry and there's various levels of drying.

Folks that are familiar with streams drying, this won't be that surprising to you. One of the things that struck me was that when we went out at the beginning of the year and we started to put some instruments in, we thought, "Oh, the pools that aren't going to dry up are going to be the really deep pools."

One of the things that you find out pretty quickly is that these deep pools, like the one that Brittany's pictured in, that are these scoured out pools that have a substrate that's cobble and gravel, they can actually be some of the first to go dry because so much of the flow can go sub-surface there.

Whereas these shallow pools, like the ones pictured in the upper right corner that have more of a bedrock substrate, it's less permeable to flows. Those are actually some of the pools that were most likely to hold water. That was an interesting observation for someone who's new to the topic of stream drying.

I want to really quickly walk through the Northwest Wild Fish Rescue, how they operate and how it's different from other fish rescue programs.

Dave and volunteers go out as early as April and start collecting fish. A key point to point out here is that they do not wait for fragmentation and drying to occur, as you can see in this picture. They go out and start scooping fish as soon as they can.

Then these fish are not released back into the wild but instead are taken to an off-site rearing facility. They are reared there from the point of capture until the following spring. They're not released in the wild, and they're not released at the end of the drought season, but instead the following spring.

Because they're stored as a mixed stock and for other reasons, they are released there. They're out planted back into the wild but not necessarily in their natal stream.

They collected about 150,000 juvenile fish in total. They're dominated by coho salmon. Typically, they collect about 15,000 to 30,000 juvenile coho salmon per year. As I describe these methods -- If you're a salmon ecologist, some red flags might go up.

We know that the hatchery rearing can have negative effects on fish. There's concerns about domestication selection. Why would you release fish back into the wild?

As a counter argument to that is that we also know that there's strong density dependence for juvenile salmonid that rear in streams. This is the reason that Chinook and coho salmon are so much less abundant than pink and chums.

If you release rescued fish back into the wild, you're probably going to be increasing fish densities in the recipient habitats where you placed those rescued fish. This could make it worse for the non-rescued fish and would likely decrease their growth and survival.

This density dependence could even be exacerbated during that first summer. We know from either experimental work or observational work such as Harvey's. Here's some of Brett Harvey's experimental work showing that low flows can reduce foraging opportunities, growth, and increased competition for juvenile salmon in streams.

Adding more fish to this situation could, potentially, not be a good thing. The key question for stakeholders and managers is, fish rescue clearly is good for the individuals that get rescue or it appears certainly if the pool they were in dries up.

It's better for one of these fish to go into a different habitat than into the stomach of a great blue heron. The question is how does this effort scale up beyond individuals to the level of population? Does it have a positive impact at the population level which is what management is more typically concerned with?

The motivation for this project was that we were discussing issues with WDFW. Two of their scientists in the southern Washington region, Thomas Buehrens and Kale Bentley, approached us about their concerns about stream drying and fish rescue.

Their agency is getting increasing demands to do something about drought. Washington's had some drought recently. Streams are drying. ESA-listed fish are dying, and they're getting increasing demands to do fish rescues.

They're also getting asked to evaluate programs like Northwest Fish Rescue. We're working with WDFW and other groups. We have been co-developing methodology to evaluate fish rescue.

Not only the Northwest Fish Rescue Program, specifically, but also to create a generalizable tool that people in other systems can use to sketch out the different possible outcomes of fish rescue. We've been working on an iterative process of developing potential methodologies and then adapting them.

Where we decided to go is to identify the key assumptions of the fish rescue program that we were evaluating and then come up with ways that we could evaluate some of those assumptions. One is that there's severe stream drying.

Severe contraction of habitats that make it so that the summer life stage is a bottleneck to population productivity. Next, that fish survival is extremely low during the summer in these drying streams.

Lastly, that fish rescue is enhancing adult returns. The way that we're evaluating these assumptions is do a combination of empirical work, measuring environmental and biological variables, and then also some lifecycle modeling.

To measure the degree of drying and habitat contraction, we're doing habitat surveys and wet/dry mapping. To determine the degree to which survival is reduced over the summer, we've been surveying fish, sampling fish, and doing mark-recapture analysis.

Lastly, we don't have long-term data on adult-returns in these systems. We don't have the potential to do something like Kevin, Mark Bengel, and others did in the Carmel River.

Instead, what we're doing is creating an empirically parameterized lifecycle model that can create a transparent and explicit way to quantitatively explore the potential cost and benefits of this program.

Brittany is a Master's student funded by this project. She's been developing this lifecycle model in collaboration with all the other people in this project. She's going to describe the model to you in a sec.

First, I want to coarsely describe some of the preliminary empirical results that we're seeing. One of the things that we thought was interesting is that we did find some substantial amount of habitats or stream reaches that remained wetted during the summer.

For example, this beaver dam pictured here. What was surprising is that water quantity didn't always translate into the presence of fish. This was a really turbid beaver pond. We didn't really find any coho salmon in it.

We're not sure if this surprising lack of fish in some wetted habitats is due to them not being proximate to spawning habitats. They're not getting seeded, or if it might be a water quality issue.

For example here, maybe, this bioturbation is causing there to be a lot of biological oxygen demand and low oxygen conditions.

Second, if you look at the picture on the bottom -- it's not one of my greatest pictures I've ever taken. What you can see here, if you look closely, is there's hundreds of juvenile coho salmon sitting motionless on the bottom of this pool.

We found that a lot of fish did find some wetted habitats, hunkered down, and survived for the summer. Right now, we're refining our mark retraction model to try to narrow our confidence intervals on what the proportion of the population that survived was.

Lastly, we put PIT tag antenna arrays at the outlets of the tributaries that we were working in. We did not see a clear pulse of emigration before stream drying.

It's possible that some fish, maybe, emigrate as fry shortly after emergence. We didn't get the sense that as the flows were declining, that fish were leaving the system and finding drought refugia elsewhere.

With that, I'm going to hand the slides over to Brittany. She's going to describe our lifecycle modeling effort.

Brittany Beebe: With that, I'd like to transition to the model by first discussing our objectives. A goal of our model is to explore the costs and benefits of fish rescue and how these cost/benefit trade-offs might differ with various rescue levels and drought conditions.

One particular trade-off that we're interested in exploring is the potential for captivity to influence survival in subsequent life stages. The benefits of fish rescue might be captured through increased adult returns or perhaps decreased probability of reaching some extinction threshold.

Costs of fish rescue, on the other hand, may be seen through reduced survival in life stages following captivity, perhaps, as a consequence of domestication or seen as increased spawner straying.

The ratio of non-rescued spawners returning, compared to rescue spawner returns, might reveal the impact of fish rescue. Lastly, it's important to note that costs may also be economic. Since our model is based on the salmon lifecycle, I wanted to just briefly discuss what this model looks like for coho.

Compared to other salmonid species, there isn't much likeage or diversity within our system. Coho generally smolts at age one, spend two summers in the ocean, and then return as age three spawners.

Jacks or age two spawners do occur, but this number is presumed to be small. Thus, we don't include it in our model.

If we take a look at the timing of freshwater life history events overlaid on a hydrograph, this one is of the East Fork Lewis River near our study site, we see that spawning occurs in November to January.

Eggs incubate until spring when they begin to emerge. Juveniles then rear for approximately a year before migrating out the following spring or early summer. The time period of particular interest to us is during the rearing phase which spans minimal to no-flow conditions in the summer, to maximum flow in the winter.

As you can imagine, a very different habitat is available throughout the duration of this rearing phase. About half of the rearing phase encompasses dry summer months. This is a potential time for fish to put on weight as larger body size is often linked to higher survival rates.

During our field surveys that we did in the summer of 2017, we saw many fish with no growth and some that actually lost weight during this time.

I also wanted to point out that the timing of this rearing phase coincides almost precisely with the timing of fish rescue. If we remember, fish are captured in early summer and then released the following spring.

Keeping this in mind, I'd like to move on to the conceptual model. First, the salmon lifecycle serves as the framework for our model.

The spawners, fry, parr, smolt, and adult life stages, which you can see as the white boxes here, represent our state variables with both fry and adults broken down further into rescued and non-rescued fish. The red arrows then are representing our state transitions or survival from one state variable to the next.

Fish rescue is included in the model through an inner pathway with captivity survival represented as the arrow from rescued fry to smolt. This state transition also represents a potential benefit of fish rescue as survival from time of capture as a fry to time of release as a smolt is much higher than that for non-rescued fish.

For example, with the Northwest Wild Fish Rescue, they state that their program has achieved a survival rate greater than 90 percent which is consistent with what we see in hatcheries.

I'd also like to point out that the captivity survival encompasses the same time frame as both the summer and winter survival for non-rescued fish. In other words, captivity bypasses the entire freshwater rearing phase.

The arrow between rescued smolts and adults then represents survival from ocean migration through a year of ocean residency. This arrow also represents a cost of fish rescue. Having been raised in captivity, rescued fish are likely ill-adapted to the natural environment and thus, experience lower post-release survival.

Another potential cost of fish rescue may occur as a loss of returning spawners due to straying. Although we are aware of this, it's not currently within the scope of our model.

Moving on then, all freshwater survivals are limited by suitable habitat availability. For spawning, this availability is of suitable spawning locations. For summer, habitat capacity is influenced by water availability. Lastly, winter survival is limited by the amounts of high-flow refuge, which is also linked to streamflow hydrology.

In the marine environments, ocean conditions influence all three marine-related survivals but not necessarily equally. For example, post-release survival of hatchery fish has been seen to decrease by up to five times compared to that of wild fish.

We plan to explore these varying differences in survival with simulations ranging from equal survival between the non-rescued and rescued fish up to this five-fold difference.

Moving back to the freshwater side of the lifecycle. I wanted to point out that drought severity in our model is controlled by adjusting summer habitat capacity. With more severe droughts represented by a lower capacity and less severe droughts by a higher capacity. We plan to simulate the population over a range of habitat capacity levels.

Summer conditions may also impact subsequent winter survival. It is expected that fish in poor body condition as a consequence of harsh drought conditions during the summer will likely have lower winter survival than those in better condition.

Like I mentioned earlier, we saw many fish with no growth and some that actually lost weight during our field season. It's expected that these fish with poor body condition at the end of summer will have a lower winter survival.

How do we begin to model our coho population? Our modeling approach follows the general methodology of Muscle and Hilborn, which uses the sequential Beverton-Holt functions.

As you can see below, this function can be rewritten to solve for survival which is the metric of our state transitions. This methodology has been widely used in various modeling efforts.

One you folks might be familiar with is the Shiraz model published by Scheuerell, et al., in 2006. More recently O. Berger, et al., adapted this approach to explore the effects of flow on coho population dynamics.

We used the sequential Beverton-Holt methodology for all of our freshwater state transitions. We assume these transitions are density dependent and include egg to fry survival, which again, is limited by spawning capacity, summer survival of non-rescued fry to parr, and winter survival from non-rescued parr to smolt.

For the remaining state transitions, we assume density independence. These survival rates are drawn from beta distributions based on values obtained from the literature.

These density independent transitions include captivity survival, which is the transition from rescued fry to smolt, as well as the marine state transitions from smolt to adult of both rescued and non-rescued fish, and also from adult backup to spawner.

Simulations will be run using various fish rescue levels. While Northwest Wild Fish Rescue typically rescues between 15,000 and 32,000 fish, additional rescue levels will be modeled including simulations of no-rescue to simulations with total or complete rescue.

Each simulation spans 99 years or 33 generations if you consider the typical coho three-year lifecycle. A thousand simulations will be run for each parameter combination.

Particular combinations we're interested in modeling are various levels of rescue, drought severity, which again, is represented by altering summer habitat capacity. Also, differences in smolt to adult survival between rescued and non-rescued fish.

We're currently refining our preliminary model and exploring our model sensitivities. We're not quite ready to share our results with you just yet. While we will be exploring a wide range of parameter values, our final model results will be tailored specifically to our system and the Northwest Wild Fish Rescue program.

With this information, we will evaluate the effectiveness of this program and have a better understanding of how the costs and benefits vary as a function of rescue level and habitat conditions.

With our model results, we will develop an interactive web application that allows users to explore the model in a way that doesn't require a sophisticated background skill set.

The R-Shiny application developed by Santorum, et al., at WDFW is pictured here. It contains slide bars to customize the model to various conditions. This is exactly what we're aiming to create for our own model.

It's our hope that managers across the Pacific Northwest might be able to use this web interface to explore the implications for fish rescue in their own systems. With that, we'd be happy to take any questions you might have.

John: Ok folks, while you guys are typing away and punching in questions or thinking about questions, we do have a quick note from Frank Emerson just noting that the volunteer rescues on the Carmel River predate that history. Thank you, Frank.

We do have a question from Jimmy Faulkner. I hope I said that right. "What method do you use to calculate K equals total habitat capacity?"

Dr. Armstrong: Hey, Jimmy. Thanks for the question. In our system, we are using the data from our fish sampling, our mark recapture, and our wet/dry mapping to relate habitat area and the extent of drying to fish capacity.

The methods will probably vary, depending on the area and what data you have. For example, if you were doing this in a context outside of drought, you might use relationships between stream length and rearing capacity to set that value.

I believe in your system, you guys have some information on survival and rearing capacity. I would think that you could put that in there. Just to be clear, K is total habitat capacity and the number of individuals.

John: Thank you, Johnny. We do have a question from Shari. "How does fish rescue work to find a long-term solution? Are you advocating this as a short-term Band-Aid while improving summer rearing habitat?"

Dr. Armstrong: That's a really great question. To be clear, we're not advocating for this program. We were approached to help them evaluate it. We're not trying to tell them "You should do this," or, "You shouldn't."

The nice thing about these models is that they could, basically, provide a quantitative hypothesis. If you're an advocate of fish rescue, you can show transparently and quantitatively why you think it's a good idea. If you're suspicious of it and you're concerned that it's not a long-term solution, you could also make those arguments with the model.

Here's an example of how you might make an argument from both sides. If, in your system, if there's really extreme drying and you have a small population size and maybe there's low marine survival, you might be able to show with this model that there's high risk of population extirpation if you don't have some level of intervention.

Whereas if you were in a system that had higher over-summer survival or, maybe, higher marine survival, you might be able to show that the population is viable without this intervention. You could show that perhaps that the second you stop the intervention, the population goes back to normal.

Those are the ways in which this tool is, hopefully, an objective tool that people can use to assess alternative hypotheses about the effectiveness of fish rescue.

John: We have a question from Bobby Flores. "When do you expect to have your analysis completed and available?"

Dr. Armstrong: That's a great question. We will have our product available before March of 2019. That's a great thing about these short projects. Half the time, I feel like when I ask someone how their simulation model's going, the answer's always that we're not done yet.

This is a finite project. We're a good way through developing the simulation model. We're going to have our Shiny app available March, 2019.

John: Another note from Shari. "In the Scott River, we saw there was no improved survival by rescuing fish. I believe that fish can use environmental cues to find cold water habitats and even survival in the isolated pools. How do you know when rescuing fish that they would survive by means not obvious to the observer?"

Dr. Armstrong: That's a great question. Our approach to it was the empirical work that we did by tracking the survival of individuals in fragmented pools and also by having our PIT tag array were we could see if fish were emigrating and, for example, moving out to the East Fork Lewis. That was our approach.

Other folks have done stuff similar. For example, if you look at Jason Hwan and Stephanie Carlson's recent work, they, basically, had PIT tagged individuals in fragmented pools.

They went back at routine intervals throughout the summer and scanned those pools for those PIT tags. What they found is that the results can vary by pool and among years, depending on winter precip. In some years there is really high mortality, especially towards the end of the summer.

John: We have a question from Neil. First, it says, "Great talk." I agree with that. "Do you have any idea of the level of genetic diversity coming into the rescue program"?

"I'm wondering, if the sampling is highly clustered. You may be getting a number of siblings in the capture of varying parts of the program and, essentially, be operating as a quasi-hatchery program."

Dr. Armstrong: That's a great question, Neil. This is a grassroots program. There's a bunch of hatchery-like tanks in the backyard. I can assure you that there's not a barn with a PCR machine in it next to it.

This is not something like the fancy hatcheries on the Klamath River where they're looking at relatedness and things like that. This is a potential concern.

I was just rereading some of the work from the Hood River out of Michael Blouin's lab on this stuff. We are thinking about, "How would you incorporate into this model potential effects of domestication beyond subsequent survival within a generation?"

For example, some prior work showing that the number of generations in captivity causes exponential decline in fitness. We're trying to figure, "If you could find a way to get that into this model to explore some of those assumptions without this having to be an individual-based genetics model that will just become intractable."

That is a really important question because some of these programs are, essentially, mini-hatcheries. From Carl Schreck's lab at OSU, other folks have found that when fish are reared in simple environments, they have different phenotypes. They can be really different fish. That's a concern and we don't have a clear answer at this time.

John: It looks like we got one more question out of Shawnsa. "Are you folks interested in investigating the genetic effects of fish rescue?" I think that was feeding off of that.

Dr. Armstrong: Follow-up on Neil's question. I think this is a really important issue. Us, individually, are not interested. I tried to do a population genetic study for my senior thesis at Lewis & Clark. I could never amplify my microsatellites, so it certainly won't be me that's doing it.

As there's increasing demands for this technique, it clearly has similarities and differences than traditional hatchery rearing. It probably has some effect on the genetics of fish. If this technique is expanded, I think it's going to be a really important topic to understand. Is there domestication selection and what are the techniques?

John: Excellent. That's all we've got for today for questions. I, once again, want to thank everyone who participated. I want to especially give a thank you to Johnny and Brittany for your presentation, and also to USGS for your continued support of this webinar series.

Thank you very much.