PNW
Pacific Northwest
Research Station

# Science
## FINDINGS

INSIDE



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*"Science affects the way we think together."*
Lewis Thomas

# SIMULATING THE CONSEQUENCES OF LAND MANAGEMENT

*A small tributary creek showing bank erosion and channel incision.*

*"It is not the strongest of the species that survives, nor the most intelligent, but the one most responsive to change."*
—Charles Darwin

The quaint notion of the "balance of nature" is a myth. The fact is, when it comes to nature, change is the only constant. Ecosystems are relentlessly shifting and morphing on all scales of time and space. Many changes are predictable over time, others less so. What was once shrubby bluebird habitat may, over time, convert to an old-growth hemlock forest. A landslide may fill a stream with logs and sediment, and suddenly it's no longer habitable for salmon—at least for a time—until the stream reworks the sediment and wood, rejuvenating the habitat. Such are the ebbs and flows of the natural world.

Ecosystem management is the science of integrating land uses into dynamic natural systems. The interactions between land use and ecosystem change are vastly complex, especially at larger landscape scales. To keep track of all the moving parts, ecologists and land managers use computer models to simulate the consequences of different actions. The models help them anticipate the outcomes of potential management decisions, thereby avoiding undesirable results.

Scientists from the PNW Research Station recently completed a suite of simulation models, which are designed to help land mangers consider the tradeoffs of management decisions in the upper Grande Ronde River watershed in northeastern Oregon. The project—called the Interior Northwest Landscape Analysis System or INLAS for short—was born out of a huge planning effort for the whole of the interior Columbia Basin. The INLAS was designed to take the themes from the larger plan and make them more tangible for land managers.

"The interior Columbia Basin planning project was so large that it was difficult to see how you could use the plans and models to provide direction for individual management actions. Managers and scientists recognized that there needed to be a way to 'step-down' the large-scale direction into something more manageable at the scale we typically work at in the Forest Service," explains Steve Wondzell, a research ecologist based at the PNW Research Station's Olympia, Washington, Lab.

Although the larger planning project was never fully implemented, the value of the INLAS-sized analysis was apparent and the initiative lived on.

IN SUMMARY

*How do you project the effects of management decisions made today on future conditions of riparian forests, stream habitat, and fish abundance in the streams and rivers of the interior Columbia Basin? Researchers at PNW Research Station have developed some novel analytical tools to help answer this question. Their work is part of the Interior Northwest Landscape Analysis System (INLAS).*

*A series of aquatic-riparian network models integrate the dynamics of riparian forest succession and natural disturbance to project change in ecological conditions under varying policy or management options. These models offer a tool that forest planners and others may use in evaluating how various management decisions could effect future forests, habitat, and fish in aquatic-riparian areas. The INLAS project researchers have recently completed a pilot-scale application of their models to the upper Grande Ronde River in northeastern Oregon. Their results have identified some areas where passive restoration may help improve salmon habitat and other areas that may be better candidates for active restoration.*

A group of scientists from the PNW Research Station along with collaborators from Forest Service, the Oregon Department of Forestry, and Oregon State University set up a pilot study in the Grande Ronde watershed to design and calibrate a series of models. They set out to create practical analytical tools that could help managers think through the consequences of action and inaction at watershed scales.

The INLAS is comprised of several modules that deal with everything from insect outbreaks, to timber harvest scheduling, to stream morphology. "Collectively, the modules illustrate a diversity of methods for modeling different resources and reflect the inherent complexity of linking models together to create a framework for integrated resource analysis," says Miles Hemstrom, a research ecologist at the Portland, Oregon, Lab.

## KEY FINDINGS

- Model results suggest that natural disturbances set upper limits for the amounts of high-quality habitat under historical conditions. For example, pool-riffle stream types provide most of the spawning habitat for spring Chinook salmon within the Upper Grande Ronde River, but historically, only about 35 percent of these reaches were in the highest quality habitat condition at any given time. Rearing habitat for juveniles was more widely distributed across the stream network, but the amount of habitat ranked as very suitable ranged between 35 and 40 percent.

- Euro-American settlement dramatically changed riparian vegetation and channel conditions, which resulted in substantial declines in habitat quality. Relative to the historical conditions, disturbances reduced stream shade and destabilized streambanks, leading to loss of undercut banks, channel widening, accumulation of fines, and increased embeddedness of streambed gravels. As a consequence, the amount of suitable and very suitable habitat for spring Chinook salmon decreased immediately under the current disturbance and land use regime.

## ECOSYSTEM CHANGE AS BOXES AND ARROWS

In 1852, Henry David Thoreau, of Walden Pond fame, coined the word *succession* to describe the predictable change in plant communities that occurs after a forest has been cleared, then left fallow. His theory that early successional plants precede and create suitable conditions for later successional species has had tremendous utility for ecologists and foresters ever since.

Take, for example, a recently burned forest, void of living plants or trees. In time, small sun-loving herbs, forbs, and grasses colonize the site and create what is called the pioneer forb state. The stand initiation state starts after a decade or so, when you see more tree seedlings than grasses and forbs. In another couple decades, canopies begin to close and some weaker trees die; this is the stem-exclusion state. Given yet more time, and assuming there are no intervening disturbances, the site will convert to the young forest state. More time still, and shade-tolerating tree species grow into the understory, and eventually the site will reach the old forest state. This is plant succession in a nutshell.

Draw these successional states in separate boxes. Now connect the boxes with arrows that indicate the duration of time it takes to transition from one box to the next. And just like that, you've built a simple state and transition model. It is just that easy—at first, anyway.

"Things get more interesting once you include disturbances, like fire and insects," explains Wondzell. "Unlike successional transitions, disturbances are probabilistic. We don't know exactly where or when they'll occur, but we do have an idea of their frequency."

Let's say, for example, that severe fires occur, on average, every 100 years in our simulated forest. The boxes and arrows are programmed into a computer, which counts the years and moves our forest along the successional path; meanwhile, it is also rolling a hundred-sided die each year to simulate the posibility of fire. When a fire occurs, the site is moved back to the beginning of the successional path and forest development starts anew.

"Without disturbance or management, all the vegetation would ultimately accumulate in one long-term stable state," says Hemstrom, who was the primary architect of the upland vegetation models in INLAS. "However, disturbance or management can change the course of vegetative development at any point. Depending on the disturbance probabilities and consequences, very little or no vegetation may actually make it to the end point of succession."

The state and transition models designed for INLAS and the Grande Ronde watershed have hundreds of potential states and dozens of different types of transitions. This complexity is required to account for all the diversity of forest types and their position on the landscape, in addition to all the management activities and natural disturbances that influence their succession. The models can simulate ecosystem change over hundreds of years, outputting an inventory of forest conditions at any time-step the user chooses.

*Purpose of PNW Science Findings*

To provide scientific information to people who make and influence decisions about managing land.

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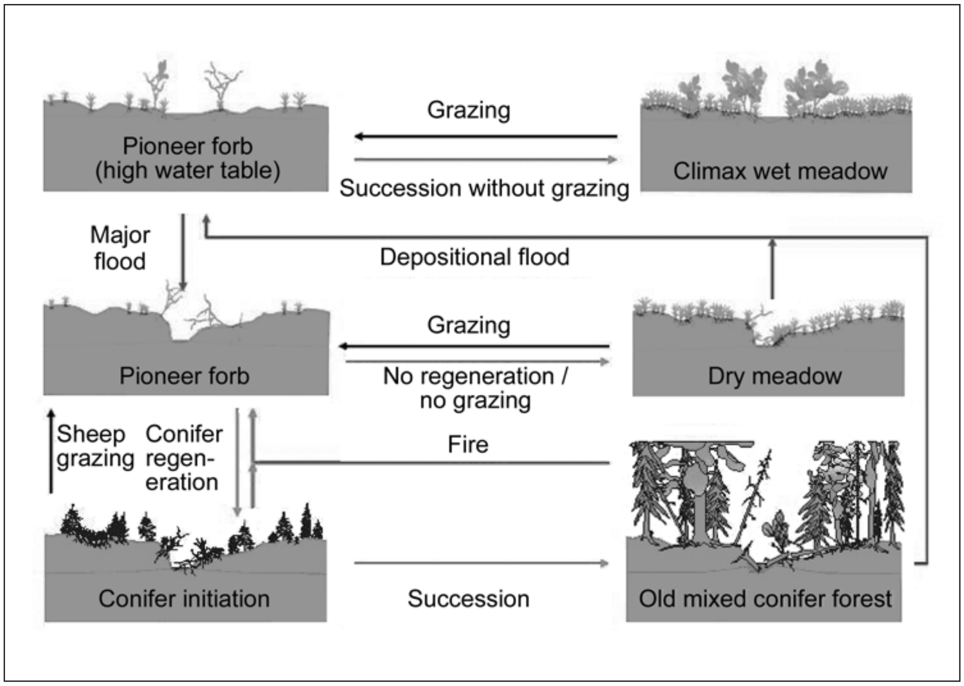
# A FRESH TAKE ON AN OLD IDEA

Because of the nature of stream systems—the linear network and small size of the riparian zones—they are not typically included in landscape-scale vegetation models. And, indeed, when Hemstrom and others first created the models for the Grande Ronde there was no stream component.

"It was as if streams didn't exist on the landscape," recalls Wondzell.

State and transition models have a long history in vegetation research. This reflects the importance of succession and disturbances in structuring vegetation across a landscape. The whole system can be intuitively distilled into a series of boxes and arrows.

"We have a different tradition for streams and geomorphology. A different way of looking at their development," says Wondzell, who led the effort to incorporate aquatic and riparian habitat into INLAS. "Even though there are processes that push streams and stream channels toward stability and disturbances that push them away from stability, no one had really described these dynamics in terms of succession."




*This is a simplified depiction of the wet-meadow state and transition model, showing only major beginning and ending "states" of successional pathways along with major disturbances that force "transitions" between the states.*

"Then, one day, I was sitting in one of our INLAS meetings, listening to Miles Hemstrom talk about his upland forest models when my mind drifted to a paper written by Wayne Elmore and Bob Beschta. Their paper describes how cattle-grazing disturbs streambank stability, leading to channel incision in wet meadows and to the growth of sage on the flood plain. Conversely, they show how the exclusion of cattle changes the stream channel, leading to a rising water table, which, in turn, prepares the way for sedges and willows," recalls Wondzell. "Then it dawned on me: these processes fit the same general template that Miles was describing about plant succession and disturbance in the upland."

Wondzell, Hemstrom, and Pete Bisson, a fish biologist at the PNW Station in Olympia, Washington, went on to develop a whole suite of new stream and riparian models to integrate with the upland models in the Grande Ronde watershed. In the tradition of the upland vegetation models, they included all the potential stream channel states, and all the different disturbances that cause the channel to transition between those states.

Like the upland models, the aquatic-riparian network models can project change in ecological conditions under varying policy or management options and can be queried at any time step to get an inventory of the condition of the stream and riparian conditions within the watershed. Specifically, the models simulate riparian vegetation succession and disturbance, the influence of episodic disturbance on stream channel morphology, and some linkages to the larger landscape.

"Our analysis is one of the first to use these types of models for assessing habitat conditions in a real stream network," says Wondzell.

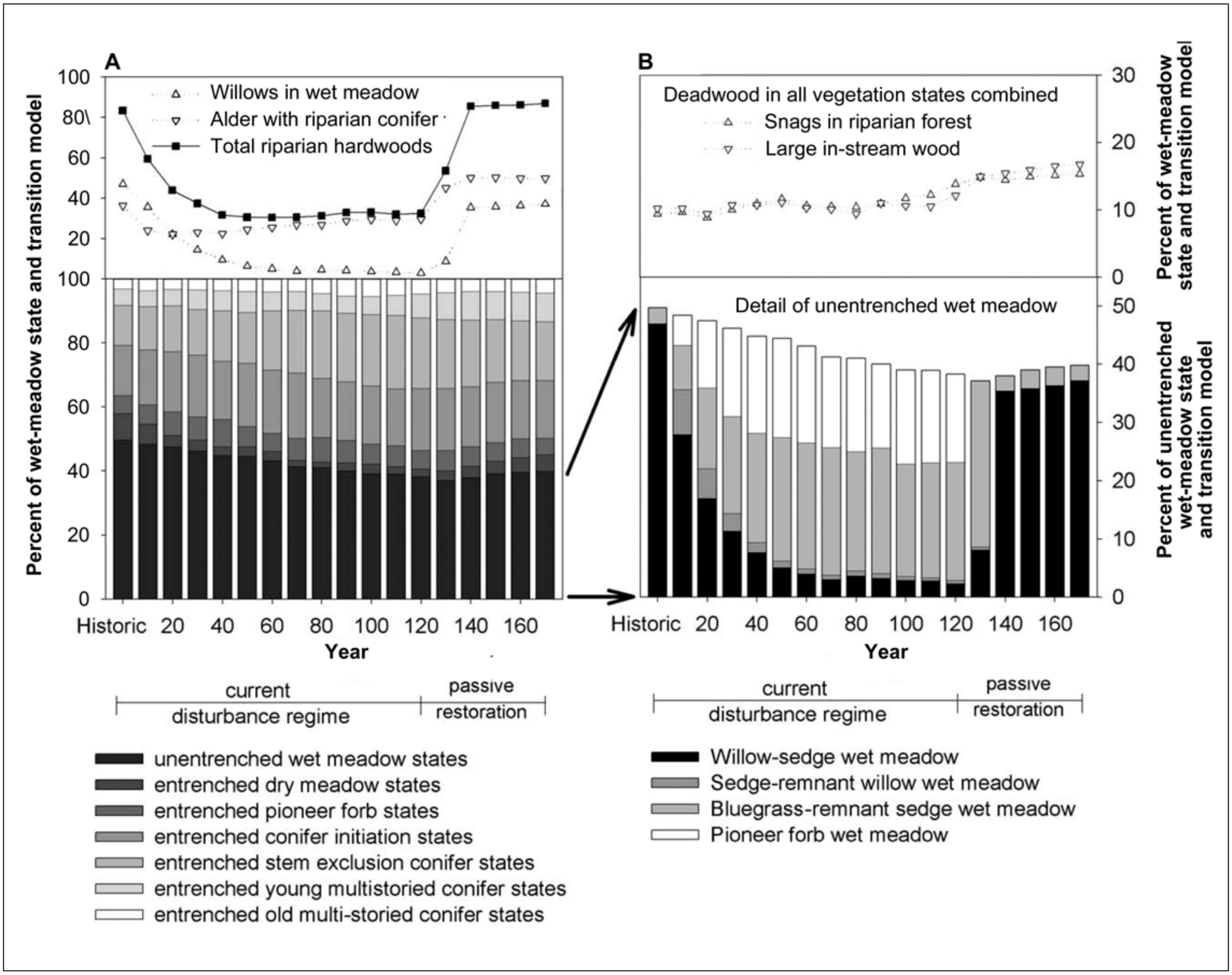
# SIMULATING CENTURIES OF STREAMS DYNAMICS

The researchers began their analysis by first modeling natural disturbances only to better understand what the stream network in the Grande Ronde would look like before Euro-American settlement. Then, they simulated the effects of natural disturbances combined with some current land uses.

"For one thing, the model results suggest that natural disturbances set upper limits for the amounts of high-quality habitat under historical conditions," says Wondzell. "For example, pool-riffle stream types provide most of the spawning habitat for spring Chinook salmon within the upper Grande Ronde River, but historically, only about 35 percent of these reaches were in the highest quality habitat condition at any given time. Rearing habitat for juvenile Chinook was more widely distributed across the stream network, but the amount of habitat ranked as very suitable ranged between 35 and 40 percent.

"In addition, our findings support what many others have found—that Euro-American settlement dramatically changed riparian vegetation and channel conditions, which

*The upper Grande Ronde River valley has some highly sinuous, pool-riffle channel forms and extensive wet meadows, which are expected in a very-low-gradient stream flowing through a wide valley floor.*




*The wet-meadows are resistant to incision as shown by the small changes in the total amount of wet-meadow states (A), but willows and other shrubs are rapidly lost from the wet meadows under severe grazing but also recover quickly once released from grazing (B).*

resulted in substantial declines in habitat quality," he adds. "Relative to the historic conditions, disturbances reduced stream shade and destabilized streambanks, leading to loss of undercut banks, channel widening, accumulation of fines, and increased embeddedness of streambed gravels. Consequently, the amount of suitable habitat decreased rapidly under the current disturbance regime."

What would happen if we ceased all grazing and other land uses around the streams in the Grande Ronde in hopes of restoring salmon habitat? Questions like this illustrate the usefulness of the INLAS models.

To provide an answer, Wondzell ran the model for a simulated 120 years using the current disturbance and land use regime, and then

## LAND MANAGEMENT IMPLICATIONS

- The models identify stream types where passive restoration is likely to be a successful management alternative. For example, wet meadows are a minor component of stream networks, but are important in the upper Grande Ronde River because they are preferred spawning locations for spring Chinook salmon. These meadows are sensitive to grazing but are also highly resilient, recovering rapidly following changes in management. Consequently, passive restoration would be rapid and effective in these stream types.

- The models also identify stream types where passive restoration is not likely to be a successful management alternative because projected recovery from natural processes is likely to be slow. For example, forested streams with pool-step structures are sensitive to loading of large wood. Our models simulate riparian forest succession and show the long time required to regrow large trees, which will eventually provide a source for large wood recruitment, and the eventual recovery of channel and habitat conditions.

*This tributary creek is located within a grazing enclosure that is high enough to exclude deer and elk, as well as cattle.*

ran it for an additional 50 years under the historical disturbance regime to illustrate the potential for a hands-off, or passive, approach to restoration.

"We were able to identify stream types where passive restoration is likely to be a successful management alternative," says Wondzell. "For example, wet meadows are a minor component of stream networks, but are important in the upper Grande Ronde River because they are preferred spawning locations for spring Chinook salmon. These meadows are sensitive to grazing but are also highly resilient, recovering rapidly following changes in management. Consequently, passive restoration would be rapid and effective in these stream types."

"The models also identify stream types where passive restoration is not likely to be a successful management alternative because projected recovery from natural processes is likely to be slow," he adds. "Forested streams, for example, with pool-step structures are sensitive to loading of large wood. We simulate riparian forest succession and show the long time required to regrow large trees, which will eventually provide a source for large wood recruitment, and the eventual recovery of channel and habitat conditions."

## A MODELER'S MAXIM: YOU REAP WHAT YOU SOW

"It is not surprising that the models said that some land uses, like severe grazing, can degrade streambanks. That's what we told it to do," says Wondzell. "With the model, we capture our best understanding of how the landscape works, formalize that into a quantitative framework, and then project that understanding over a watershed and through time. When we find things that clearly fail to match the real world, we know our model—and likely our understanding—is either incomplete or worse, just plain wrong. The converse is not true. If the model makes sense, we cannot conclude that it is correct—it just reflects what we already think we know."

Right now, the models are still prototypes. And, according to Wondzell, their real usefulness won't be realized until the relations within the models can be calibrated with site-specific data and then applied by managers to a local watershed to compare several management strategies.

Wondzell is optimistic that the models will see broader application. "Our models are relatively simple to develop and run, making them relatively easy to modify and use in a variety of landscape analyses. In fact," he adds, "I bet if I sat you down at my computer, I could have you running different management scenarios within an hour."

In addition, the models are based on geomorphic processes and riparian vegetation dynamics common throughout the interior Columbia River basin making them broadly portable to land planning efforts throughout the basin.

For now, the INLAS researchers will continue refining the model for the Grande Ronde watershed, trying to distill all the complexities and dynamics of nature into a tangle of boxes and arrows in order to help managers weigh their options for the future.

*"One thing at a time,*
*all things in succession."*

—J.G. Holland

## FOR FURTHER READING

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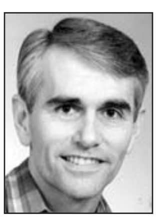

PETE BISSON leads an aquatic research team at the Forest Service's PNW Research Station in Olympia, Washington. He worked as an aquatic biologist for the Weyerhaeuser Company for 21 years prior to joining the Forest Service in 1995. His research has included stream habitats and food webs, riparian zone management, and a variety of conservation issues related to aquatic ecosystems. He holds affiliate faculty appointments at the University of Washington, Oregon State University, and the University of Idaho, and has served on two National Academy of Sciences committees: one on Pacific salmon and the other on watershed management. He has edited books on watersheds, river restoration, Pacific salmon, and sea-run cutthroat trout.

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