

Science

FINDINGS

INSIDE

Bringing All the Cards to the Table.....2
Modeling How a River Runs Through It.....3
Connecting the Dots.....4
Taking It Back to the River5

issue one hundred thirty nine / february 2012

“Science affects the way we think together.”

Lewis Thomas

Thinking Big: Linking Rivers to Landscapes



Roy W. Lowe/USFWS

Newly available biological monitoring and landscape-scale data allowed researchers to more fully explore connections between landscape characteristics, human land use, and instream conditions in the Oregon Coast Range.

“No river can return to its source, yet all rivers must have a beginning.”

—Native American Proverb

Rivers begin as rain on ridgetops and eventually flow into the sea, shaping and being shaped by the entire landscape along the way. Underlying geology determines the extent to which a river erodes rock while topography dictates river gradients. The distribution of forests controls how much wood enters the stream. Landscape-scale climate patterns, such as uneven rainfall and gradients of air temperature, also

contribute to differences in flow and water temperature across the stream network. Together, these interactions influence freshwater habitats and plant and animal communities.

Researchers are finding ways to capture this big picture and develop tools that statistically link landscape characteristics to local stream conditions and fish abundance. These tools are facilitating monitoring and management of freshwater habitat in the Oregon Coast Range, particularly for coho salmon.

Monitoring fish populations and stream conditions over time provides feedback

IN SUMMARY

Exploring relationships between landscape characteristics and rivers is an emerging field of study, bolstered by the proliferation of satellite data, advances in statistical analysis, and increased emphasis on large-scale monitoring. Climate patterns and landscape features such as road networks, underlying geology, and human developments determine the characteristics of the rivers flowing through them. A multiagency team of scientists developed novel modeling methods to link these landscape features to instream habitat and to abundance of coho salmon in Oregon coastal streams. This is the first comprehensive analysis of landscape-scale data collected as part of the state’s Oregon Plan for Salmon and Watersheds.

The research team found that watershed characteristics and human activities far from the river’s edge influence the distribution and habitats of coho salmon. Although large-scale landscape characteristics can predict stream reaches that might support greater numbers of coho salmon, smaller scale features and random chance also play a role in whether coho spawn in a particular stream and in a particular year. The team developed new models that successfully predicted the distribution of instream habitat features. Volume of instream wood and pool frequency were the features most influenced by human activities. Studying these relationships can help guide large-scale monitoring and management of aquatic resources.

on management actions. In the Pacific Northwest, natural resource agencies have traditionally collected data on freshwater fish at “index” sites—easy-to-access locations where fish tend to be abundant. Studies based on those convenient data sets had yielded certain conclusions regarding landscape influences on streams in other areas.

Would these conclusions apply to the full range of stream types randomly sampled along the Oregon Coast? A multiagency team, including Ashley Steel and Kelly Burnett, scientists with the Pacific Northwest (PNW) Research Station, used newly available large-scale data, satellite imagery, and statistical advances to answer this question.

| KEY FINDINGS | |
|--------------|--|
| • | Factors that influence and characterize landscapes are useful in explaining and predicting the distributions of fish and instream habitat characteristics. |
| • | Conditions far from stream banks affect the distribution of key instream habitat characteristics. Amount of instream wood, percentage of gravel, and pool frequency, which are essential to healthy salmon habitat, are particularly sensitive to land use. |
| • | The previous practice of monitoring only the good “index” stream sites may have impaired scientific understanding of how landscape characteristics affect rivers and aquatic organisms. |
| • | Landscape characteristics were useful for understanding the best sites, but were relatively poor predictors of the presence of coho salmon at any particular site and in any particular year, suggesting that finer-scale processes and random chance may guide year-to-year distribution. |

BRINGING ALL THE CARDS TO THE TABLE

In 2005, Ashley Steel, a quantitative ecologist, was developing statistical tools to link landscapes and steelhead, a species of Pacific salmon. When Phil Larson, a fisheries ecologist with the Pacific States Marine Fisheries Commission, heard Steel present her work, he recalls: “The bulbs continually flashed in my head. What an opportunity to extend Ashley’s statistical expertise to the incredible new large-scale data set from the state’s Oregon Plan for Salmon and Watersheds, which included data from randomly sampled instream habitat with both coho salmon adult spawners and juveniles.”

Kelly Burnett, a research fish biologist, explains: “In most of the papers linking landscapes and streams that had been written up to this point, people said if only we had data from a random sample and if only we had data sampled over very large areas. This was an opportunity to meet these ‘if only’ needs.”

As part of the Oregon Plan for Salmon and Watersheds, the Oregon Department of Fish and Wildlife (ODFW) had collected a random sample of all possible habitats—good sites where fish numbers and habitat quality were expected to be high, along with marginal sites that were unlikely to have many fish. The random, “probabilistic” nature of the sampling ensured, to the degree possible, that the data were representative of the entire Oregon Coast region. These data were collected over nearly a decade, providing not only a “big picture” perspective over space, but also a long-term perspective over time. The ODFW also had collected long-term data on coho salmon spawners from index sites in the same region, which could be



Rick Swart/ODFW

Oregon Coast coho are listed as a threatened species under the Endangered Species Act.

used to compare results between landscape models. Supplementing this rich data set was the PNW Research Station’s extensive landscape data from its Coastal Landscape Analysis and Modeling Study (CLAMS).

Thus began a working group to study how landscape features could be used to understand and predict coho salmon populations and instream habitat quality throughout the Oregon Coast Range. The diverse group consisted of fisheries scientists, landscape and river ecologists, spatial analysts,

statisticians, and modelers representing four government agencies.

“A big piece of what made this study successful was how we accomplished the science,” reflects Burnett. “This very large collaboration was built from the ground up. It was an effort to link these landscape data layers to the habitat and stream data, and then tie them all together with the statistical tools. By bringing all of our cards to the table, we were able to do what any one member of the group would have been unable to do on their own.”

MODELING HOW A RIVER RUNS THROUGH IT

Understanding how to preserve and maintain freshwater habitats while the surrounding landscape is managed to meet other societal needs is essential to managing and protecting coho salmon in particular and to preserving the integrity of aquatic ecosystems in general.

The researchers addressed five questions about how landscape features drive what happens within the rivers that flow through them: (1) Are abundances of adult coho salmon better predicted by landscape data considered locally near a stream or over larger areas? (2) Can conclusions from index sites be extrapolated to the entire range of stream reaches? (3) Which landscape features best predict adult coho salmon abundance and distribution? (4) How are human actions distributed across the landscape, and does the pattern of human development affect our modeling? (5) Can we detect influences of human activities on indicators of habitat quality?

The research team customized statistical approaches to answer each question. For example, they built a mixed-effects model

Purpose of PNW Science Findings

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

PNW Science Findings is published monthly by:

Pacific Northwest Research Station
 USDA Forest Service
 P.O. Box 3890
 Portland, Oregon 97208

Send new subscriptions and change of address information to:

pnw_pnwpubs@fs.fed.us

Rhonda Mazza, editor; rmazza@fs.fed.us

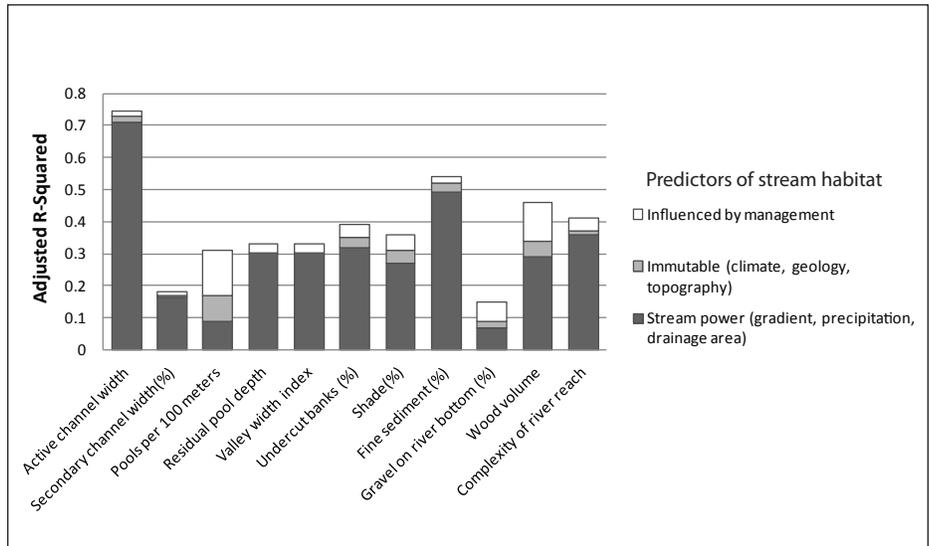
C. Hugh Luce, layout; chluce@fs.fed.us

Science Findings is online at: <http://www.fs.fed.us/pnw/publications/scifi.shtml>

To receive this publication electronically, change your delivery preference here:

<http://www.fs.fed.us/pnw/publications/subscription.shtml>

USDA United States
 Department
 of Agriculture



Proportion of variability (adjusted R-Squared) in 11 stream habitat variables that can be attributed to management-influenced predictors, immutable predictors, and stream power indicators. The white area at the top of each stack suggests how much variation can be explained by management-influenced variables after the immutable predictors, including stream power, have been incorporated into the model.

to accommodate natural year-to-year fluctuations in coho salmon population size, while extracting consistent signals of landscape predictors on fish abundance. They designed a two-step modeling approach to distinguish between sites where coho were and weren't observed, and then predict abundance in sites where coho had been observed. And they built a set of structured models to isolate the effects of human activities on the distribution of important instream habitat features.

"Each data set has its own quirks, which bring both headaches and opportunities," Steel explains. "If we want to answer questions of importance to management or monitoring or science in general, we have to customize the model-building approach to deal with the data quirks and to match the particular question of interest."



Volume of instream wood and pool frequency are habitat features particularly sensitive to human land uses.

Modified from Anlauf et al. 2001.

U.S. Forest Service

CONNECTING THE DOTS

Some of their results confirmed findings from similar studies in other regions. For example, using the index data, the research team found only small differences between models that used data from riparian buffers and those that used data from an entire drainage basin.

Winter temperature range and amount of erosive rock popped up as important variables in predicting abundance of coho salmon in all of the models using index data. The riparian buffer models were slightly less effective at predicting abundances of spawning coho salmon, so the research team built the next set of models using landscape data summarized over large areas.

When the researchers built the first models with the new, randomly sampled data, they were surprised that the models didn't predict the data well. They had expected the larger data set to conclusively link landscape conditions and fish populations. Instead, the models couldn't predict if adult coho would be present or absent in a particular location or year.

Where fish were present, the models based on landscape characteristics did a reasonably good job predicting how many fish might be there. Annual winter temperature range, the percentage of agriculture and forested area in the drainage basin, and a combination of stream gradient, width, and flow (intrinsic habitat potential) were significant factors in predicting how many fish might be observed.

Based on these findings from the random data, the research team concluded that fine-scale processes and random chance determine if any returning adult fish find a particular reach in a particular year. If fish can find it, then landscape features may play a role in how many fish come to the party.

"If we knew fish were there, the landscape models could predict which sites would be awesome, great, or pretty good," Steel explains. "We were surprised to discover that making predictions about where fish would show up in the marginal, fringe habitat was hard. That kind of insight would never have happened without people collecting data in areas other than the most productive habitats."

The research team concluded that the past focus on index sites and use of other nonrandom monitoring data sets may have limited scientific understanding of how landscape characteristics affect species distributions.

The researchers were able to separate the influence of human activities from factors

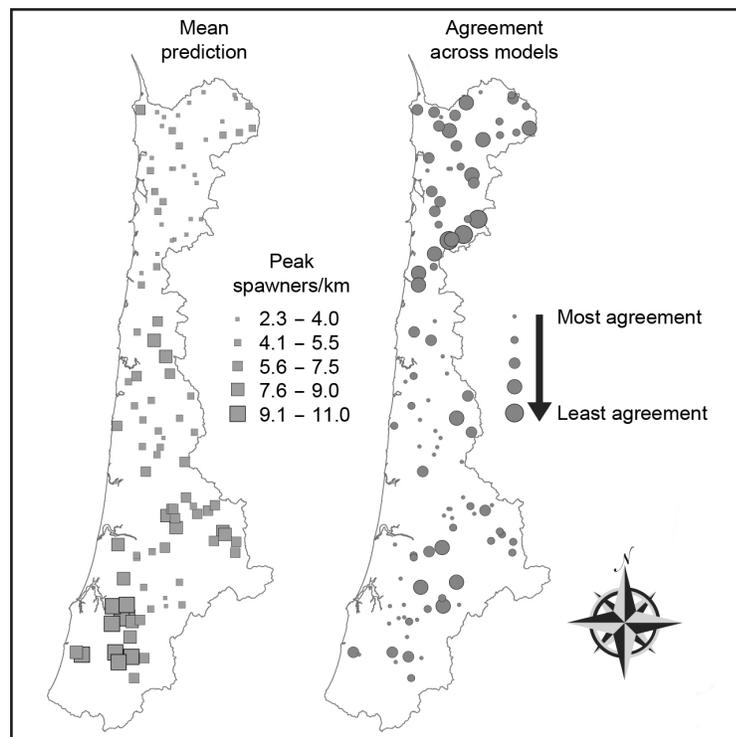


Sam Beebe

Some of the same landscape characteristics that influence formation of instream habitat, such as low gradients and wide valleys, also influence land-use decisions by humans. This can make it difficult to determine the root effect of correlated variables in statistical models.

over which people have little to no control, such as geology, elevation, and stream power. Through this filter, the volume of instream wood, pool frequency, undercut banks, gravel, and shade emerged as the instream habitat features that are particularly sensitive to land-use pressures. Predictive maps of these features can help resource managers and scientists identify areas where the conditions suitable for a particular species might exist.

"Relationships may be more obvious with landscape characteristics and the physical habitat than with the fish," notes Burnett. "If you remove all the trees along the stream, the likelihood that you're going to find logs in the stream will be low. But establishing such a clear and direct connection between what we do on the landscape and a fish response can be more difficult, particularly for migratory fish like salmon. Exploring factors such



The left map shows averaged density projections of coho salmon spawners in randomly selected stream segments from four models that use data collected at different spatial scales.

The right map shows the level of agreement among the four models. When compared to the northern portion of the Oregon Coast Range, greater agreement among model projections is found to the south. Scientists are now looking for reasons to explain the differences.

Modified from Firman et al. 2011.

as predation or timing of migration in combination with water flows will probably be necessary to fully explain fish distribution and abundance.”

People have habitat preferences too, which means roads and human development are not distributed haphazardly across the landscape. “People purposefully correlate their activities with landscape features,” Steel says. Along the Oregon Coast, for example, human development is clustered in the valleys. Deep flood plain soils, topography, and amount of precipitation, for example, make these areas desirable for human uses and are some of the same immutable landscape features that also influence the formation of instream conditions for salmon. “It’s really more difficult to untangle the correlations than we thought it would be,” Steel says.

“We also found that the correlations between natural and human-made features change, depending on the scale of the analysis.” When the researchers broadened the scale of analysis from riparian buffers to entire watersheds, for example, it added steeper



LAND MANAGEMENT IMPLICATIONS



- Landscape conditions far from the river’s edge may have strong impacts on instream conditions. Understanding the effects of natural processes and human activities across entire drainage basins is key to researching, monitoring, and restoring aquatic resources.
- Considering a combination of fine-scale and landscape-scale habitat drivers can increase the chances of success in sustainably managing and conserving coho salmon populations.
- In addition to looking at healthy habitats, monitoring programs for freshwater resources may benefit from increased emphasis on marginal habitats, where patterns of fish occupancy may be better quantified.
- Landscape-scale assessments can provide mapped estimates of instream conditions or fish abundance that are useful for planning land-use and restoration activities before on-the-ground assessments are available.

hillslopes, higher elevations, and older forests but little additional valley area. “Our results highlighted the need for carefully thinking about the dynamic nature of the data sets and about how variables are related

to one and other,” Steel observes. The scientists are currently experimenting with computer simulations to find a way to best incorporate these shifting relationships in landscape models.

TAKING IT BACK TO THE RIVER

River systems can be vast, and it is not feasible to collect fine-scale data for each stream and fish population. Landscape-scale data can be easier and less costly to obtain. Tools that can use landscape-scale data to help scientists understand and accurately predict the distribution of habitat and fish from landscape-scale data have great utility in guiding conservation and restoration efforts.

Monitoring programs for freshwater resources may benefit from increased emphasis on marginal habitats where patterns of fish occupancy can be better quantified.

Focusing on unique areas where relationships between human land uses and natural landscape gradients break down also may help untangle these commingled drivers of river condition and salmon distribution. Along the Oregon Coast, for example, monitoring in the few valleys with very little human development may help differentiate the natural functions of valleys from the impacts of development.

“Humans have made different sized footprints across the landscape,” Steel explains. “When we monitor, we want to make sure we’re monitoring across a range of areas. When you

haven’t collected information across the full range of river conditions, you’re missing half the story.” She continues: “The next step is to examine other places with large-scale monitoring programs to see if patterns are similar to what we found on the Oregon Coast.”

“Any river is really the summation of the whole valley. To think of it as nothing but water is to ignore the greater part.”

—Hal Borland, *This Hill, This Valley*

FOR FURTHER READING

Anlauf, K.J.; Jensen, D.W.; Burnett, K.M.; Steel, E.A. [et al.]. 2011. Explaining spatial variability in stream habitats using both natural and management-influenced landscape predictors. *Aquatic Conservation: Marine and Freshwater Ecosystems*. 21: 704–714.

Firman, J.C.; Steel, E.A.; Jensen, D.W.; Burnett, K.M. [et al.]. 2011. Landscape models of adult coho salmon density examined at four spatial extents. *Transactions of the American Fisheries Society*. 140: 440–55. DOI: 10.1080/00028487.2011.567854.

Lucero, Y.; Steel, E.A.; Burnett, K.M.; Christiansen, K. 2011. Untangling human development and natural gradients: Implications of underlying correlation structure for linking landscapes and riverine ecosystems. *River Systems*. 19: 207–224.

Steel, E.A.; Hughes, R.M.; Fullerton, A.H.; Schmutz, S. [et al.]. 2010. Are we meeting the challenges of landscape-scale riverine research? A review. *Living Reviews in Landscape Research* 4. <http://landscapere-search.livingreviews.org/Articles/lrlr-2010-1/>.

Steel, E.A.; Jensen, D.W.; Burnett, K.M.; Christiansen, K. [et al.]. [In press]. Landscape characteristics and coho salmon (*Oncorhynchus kisutch*) distributions: explaining abundance versus occupancy. *Canadian Journal of Fisheries and Aquatic Sciences*.

WRITER’S PROFILE

Joan O’Callaghan writes and edits publications about a variety of issues including environmental protection, resource conservation, and energy efficiency. Her company, Communications Collective, is based in Bethesda, Maryland.

Science

FINDINGS

U.S. Department of Agriculture
Pacific Northwest Research Station
333 SW First Avenue
P.O. Box 3890
Portland, OR 97208-3890

Official Business
Penalty for Private Use, \$300

PRSR STD
US POSTAGE
PAID
PORTLAND OR
PERMIT N0 G-40

SCIENTIST PROFILES



E. ASHLEY STEEL is a quantitative ecologist and research statistician with the PNW Research Station. For this project, she designed the statistical analyses linking landscapes to rivers, helped to

formulate research questions of management relevance, and led the early phases of the collaboration. She is currently collaborating on similar analyses linking fish communities and landscapes across Europe.

Steel can be reached at:

USDA Forest Service
Pacific Northwest Research Station
400 N 34th Street, Suite 201
Seattle, WA 98103
Phone: 206-732-7823
E-mail: asteel@fs.fed.us



KELLY M. BURNETT is a research fish biologist with the PNW Research Station, Land and Watershed Management Program. For this research project, she worked to develop study objectives and approaches,

obtain funding, and incorporate ecological principles into the analytical framework. She is currently leading follow-up research to model relationships between landscapes and juvenile coho salmon.

Burnett can be reached at:

USDA Forest Service
Pacific Northwest Research Station
3200 SW Jefferson Way
Corvallis, OR 97331
Phone: 541-750-7309
E-mail: kellyburnett@fs.fed.us

COLLABORATORS

Kara Anlauf and Julie Firman, Oregon
Department of Fish and Wildlife

Kelly Christiansen, Pacific Northwest
Research Station

Blake Feist, Northwest Fisheries Science
Center, National Oceanic and Atmospheric
Administration Fisheries

Phil Larsen, Pacific States Marine
Fisheries Commission

Oregon Watershed Enhancement Board