PNW
Pacific Northwest Research Station

Science FINDINGS

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

LINKED IN: CONNECTING RIPARIAN AREAS TO SUPPORT FOREST BIODIVERSITY

William Leonard

Establishing protected links between headwaters may benefit species such as the torrent salamander and other amphibians that disperse overland to neighboring drainages.

IN SUMMARY

Many forest-dwelling species rely on both terrestrial and aquatic habitat for their survival. These species, including rare and little-understood amphibians and arthropods, live in and around headwater streams and disperse overland to neighboring headwater streams. Forest management policies that rely on riparian buffer strips and structure-based management—practices meant to preserve habitat—address only some of these habitat needs. They generally do not consider the overland connectivity necessary for these species to successfully move across a landscape to maintain genetically diverse populations.

Management in headwater areas also can affect downstream salmon habitat. Landslides and debris flows initiated in these areas can severely degrade habitat by dumping too much sediment and not enough large wood into the stream. Carefully managing sensitive headwater areas can aid not only amphibians and arthropods, but also threatened salmon populations and other forest organisms.

Pacific Northwest Research Station scientists are exploring scenarios for protecting headwaters by extending riparian buffers and connecting them over ridgelines to neighboring drainages. A range of management practices designed to achieve multiple objectives may be appropriate in these protected areas to facilitate cost-effective, ecologically integrated management plans. Headwater links could piggyback on lands that are already protected and could consider such factors as sensitivity to debris flows and landslides, land ownerships and objectives, and climate change.

"The one process now going on that will take millions of years to correct is the loss of genetic and species diversity by the destruction of natural habitats. This is the folly our descendants are least likely to forgive us."
—Edward O. Wilson

It begins as a seep or spring—fresh, clear water welling above the ground high in the mountains. From its source, a headwater stream supports numerous life forms, including amphibians and arthropods. As it meanders downhill, it carries along, moves to avoid, or backs up behind the rocks, logs, soil, leaves, and other organic matter it encounters. When deposited downstream, this material forms critical habitat, including spawning ground, for larger species such as salmon and trout.

Just over the ridgeline, a similar process is going on, headed down another stream channel. Between the two headwater streams, amphibians such as torrent salamanders trek overland to colonize and reproduce. However, certain management practices can compromise those essential connections for amphibians. Also, land disturbances upslope from the headwater can affect the quality of downstream habitat for fish.

Current efforts to protect and enhance forest biodiversity tend to categorize species as either water or land dwellers, yielding independent conservation networks with little overlap among protected habitats. For example, provisions for structure-based management (management that encourages variable-aged stands, keeps snags and downed logs, and maintains healthy undergrowth) were mandated to help maintain rich habitat

KEY FINDINGS

- Decisions about where to link habitat at the landscape scale could prioritize connections across latitudinal and altitudinal gradients to aid species' dispersal in response to predicted climate change.
- Protected areas at the drainage-basin scale could take into account known locations of target species, existing protections, land ownership patterns, and disturbances such as landslides and debris flows.
- At the forest-stand scale, habitat links could extend riparian management zones into nonbuffered headwater streams and connect riparian buffers across ridgelines.

U.S. Forest Service

Management activities that affect headwater conditions can have a ripple effect, either positive or negative, on aquatic habitat used by salmon and other species further downstream.

for terrestrial species, and guidelines for protective buffers along riparian areas were established largely to safeguard habitat for fish and riparian species. Although these policies have afforded certain essential protections, they do not necessarily meet the needs of species that depend on both land and water resources. Strategically overlapping protected areas could facilitate more cost-effective management practices while providing overland connectivity for terrestrial/aquatic species such as amphibians, promoting healthy fish and riparian habitat, and fostering biodiversity.

MERGING TWO DISCIPLINES TO STRENGTHEN THE SCIENCE

Pacific Northwest (PNW) Research Station scientist Deanna Olson is deeply concerned about the loss of aquatic and terrestrial forest habitat. "Habitat loss is probably the most severe and pervasive cause of biodiversity loss across the globe," she says. "It is what most species are facing first and foremost."

Olson is in the midst of a long-term study on the biology and ecology of amphibians in forested headwater basins and drainages. Since the early 1990s, she has cataloged and characterized the species that live in headwater systems and studied the effects on their habitat of various riparian buffer widths in forests that have been managed by thinning.

Olson's colleague, PNW Research Station scientist Kelly Burnett, studies watersheds and streams at the landscape scale and the effects of upland disturbances on salmon habitat. Using widely available data, she has mapped streams across Oregon's Coast Range to assess their susceptibility to debris flows and their "intrinsic potential" to provide high-quality habitat for salmonids.

Olson and Burnett recently combined their research findings to provide forest managers with information for better understanding and assessing the economic and ecological tradeoffs inherent in various timber and riparian management strategies. They developed a framework for linking headwater drainages to provide habitat connectivity for amphibians and other species that live in water and on land.

Loretta Ellenberg

The coastal tailed frog is one of many species that likely would benefit from linked headwaters that facilitate connectivity among the gene pools of subpopulations in adjacent watersheds.

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pnw_pnwpubs@fs.fed.us

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

Cheryl Jennings, layout; cjennings@fs.fed.us

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AMPHIBIANS: OVERLAND DISPERSAL

Some amphibians live only in or near headwaters. One of these is the southern torrent salamander, a species of concern owing to habitat loss. These small, secretive creatures thrive in closed-canopied forests and hang out in gravelly or rocky areas in the uppermost reaches of headwater areas. "Exactly how they're moving overland is something we don't entirely know," says Olson. "Several river drainages in the Oregon Coast Range run almost perpendicular to the ocean and are not connected to one another by freshwater. Yet the amphibians occur in all headwaters, so we assume they are moving overland." They appear to inch their way over ridgelines to other headwaters, one leaf, one branch, and one rock at a time.

David Leer

The coastal giant salamander breeds in forested headwater streams and becomes terrestrial later in life.

To develop a more comprehensive understanding of amphibian evolution and movement capabilities, Olson is currently collaborating with geneticists to assess gene flow. "We're starting to get some information now about connections among the different populations and what their movement capabilities are," she says. "This will allow us to test the assumption that they are moving overland—and how—and help us to understand better what particular locations on the landscape need protection."

Another amphibian associated with headwaters is the coastal tailed frog, which breeds in high mountain streams and, in favorable conditions, will disperse through intact forested landscapes. The species is vulnerable in areas where its habitat has been disturbed by past logging activities that increased sedimentation in streams and resulted in higher surface temperatures where more sunlight reaches the ground.

Olson says protecting habitat in and around headwaters is important to ensure that the routes for migration of these and numerous other amphibian and arthropod species are not compromised. Riparian buffers can help, but they may not adequately provide the necessary terrestrial connectivity to allow these species to move among protected habitats.

SALMON, DEBRIS FLOWS, AND LANDSLIDES

Meanwhile, Burnett and her colleagues have developed models to accurately map the numerous headwater streams of the Oregon Coast Range and identify those that are most likely to be affected by debris flows. Landslides and debris flows initiated from hill slopes in headwater areas can strongly influence a stream channel's health. Burnett is interested in which streams will route debris flows to important fish habitats downstream. "We identified the areas in the stream channel that have the highest potential for developing high-quality habitat for salmon, and the areas on the hill slope that have highest potential to affect those in-channel areas," she explains.

Left to its own devices and given enough time, nature creates the necessary habitat for creatures that live in or near streams and their drainages. Extreme weather events can create landslides and debris flows in any forested landscape. In the short term, rainstorms, windstorms, and wildfire can severely degrade fish habitat by causing debris flows that dump huge volumes of sediment, large wood, and boulders into the stream channel, says Burnett. Over the longer term, however, the stream can transform this mess into patches of clean, well-sorted spawning gravel and complex cover for hiding—key elements of good salmon habitat. "Under a natural disturbance scenario, some habitats were coming into high-quality states while others were being buried and degraded—this would have been going on all over the landscape," she says.

Certain management activities can tip the balance by creating more frequent debris flows that deliver lots of sediment but not much large wood. Under those scenarios, a stream is unlikely to eventually create high-quality habitat after a debris flow. "With careless management of these sensitive uplands, you just get the bad without the good," Burnett says.

Burnett and her team developed a model to predict which areas are prone to landslides and debris flows that could affect headwater streams. "Armed with this information," she says, "land managers can tailor activities to sensitive areas. For example, in sensitive areas, they might avoid harvesting and road construction altogether, or thin to accelerate large wood characteristics—grow bigger trees faster—so that when wood is delivered to a stream channel it is large enough to help develop complex habitat."

Dan Shively

In the short term, landslides can severely degrade aquatic habitat, but over time the wood and gravel they deliver to the stream can contribute important structure for aquatic habitat.

INTEGRATION: MINDING THE HEADWATERS

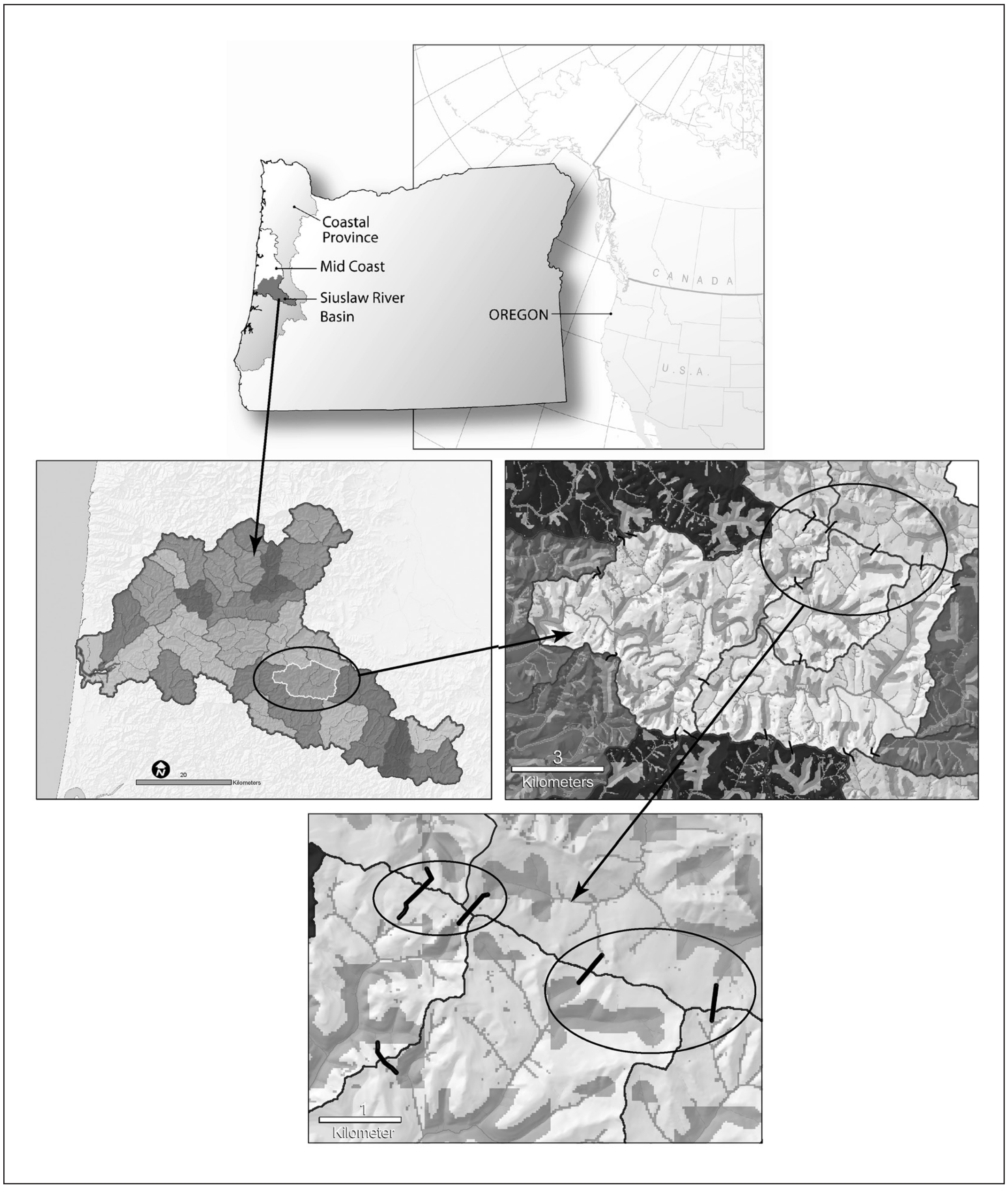
Headwater connectivity over ridgelines is important for amphibians, and caring for headwaters to ensure quality downstream habitat is important for salmon. “In the past when people thought about salmon habitat, they considered only the riparian area—the streamside area—immediately adjacent to where the fish actually live,” Burnett says. “Now we know that headwater areas are important to salmon and that debris flows connect salmon and headwaters.”

What is good for amphibians and salmon will likely benefit numerous other forest-dwelling species, especially those that have small home ranges or limited abilities to move, such as fungi and invertebrates. To protect headwater areas and support these species, Burnett and Olson developed design considerations for linking habitat at three spatial scales: landscape, drainage basin, and forest stand. As a case study, they also developed a scenario for headwater linkage areas to provide a minimal level of connectivity throughout Oregon’s Coast Range.

In their example scenario, the scientists began by identifying only one link between each small headwater basin across the landscape, which resulted in about 5,000 linkage areas. This would connect approximately 15 percent of the headwaters in an approximately 5.7 million-acre area of western Oregon.

As they contemplated where to locate linkage areas, Olson and Burnett looked at ridgelines between large, discrete basins that have no freshwater stream connection. These are particularly important for amphibian connectivity across the landscape because downstream dispersal pathways along riparian corridors are not sufficient to connect such basins.

Kathryn Ronnenberg



A case study in the Oregon Coast Range illustrates what placement of habitat linkage areas could look like at different scales. Decisions about linkage placement could be based on climate-change scenarios, ownerships patterns, existing protected areas, or other factors.

Headwater locations connecting more than two of these basins might be areas to consider for protected links. The Oregon Coast Range has approximately 20 locations where at least three large basins connect at headwater ridgelines, thus creating what Olson calls a “headwater triad.” For example, three basins join and form a headwater triad at Marys Peak—the highest peak in the mountain range. These headwaters drain east into the Willamette Valley, northwest toward Newport, and southwest toward Waldport. Triad linkage areas like Marys Peak could offer multidirectional dispersal connections for aquatic-terrestrial species such as amphibians.

“This may be an additional consideration for where to put your management emphasis, because in a relatively small area you can connect across three basins—more bang for your buck, so to speak,” says Olson. “This is something we’re looking at a little more closely. A dozen well-placed linkage areas at a very large spatial scale could have significant effects.”

Another issue at the landscape scale includes climate change. “We’re suggesting linkage areas from low elevation to high elevation be considered, and also linkages across latitudes. Put the linkage areas at the southern end of a basin and at the northern end of a basin to link across neighboring watersheds,” says Olson.

Such connections could allow species to be more resilient to climate change or other disturbances. For amphibians or organisms with complex life histories, these links could provide dispersal habitat to aid movement into areas with more suitable breeding, foraging, or overwintering habitat.

At the drainage-basin scale, Olson and Burnett suggest piggybacking headwater protections on areas that have already been identified as sensitive, such as landslide-prone areas that could influence fish habitat or old-growth stands that have been set aside for protected species like the northern spotted owl and marbled murrelet.

LAND MANAGEMENT IMPLICATIONS

- Science-based guidelines are available for developing and managing habitats for species that use both aquatic and terrestrial habitat.
- Linkage areas may be a cost-effective means to provide dispersal corridors for headwater species and can be implemented in concert with other management designs, such as those protecting debris-prone areas.
- Habitat links can target sensitive headwater species by design, but also can result in a web of connection across the landscape that is expected to benefit a host of forest-dependent species, including threatened salmonids.

MANAGING LINKAGE AREAS

At the forest-stand scale, a linkage area would not necessarily be a "hands-off" reserve. "It can be a managed forest," says Olson. "We provide suggestions for a toolbox of management practices that you might apply in a linkage area." For example, when thinning is applied outside riparian buffer zones, narrower buffers may be effective at maintaining many habitat conditions, she says.

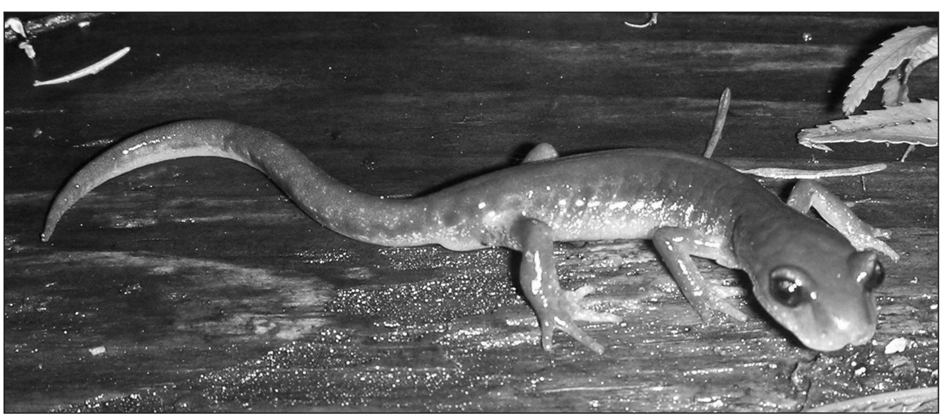
Management practices could extend riparian management zones into headwater streams and connect riparian buffers across a ridgeline. At the forest-stand scale, various silvicultural practices such as retaining downed wood and leaving uncut clusters of trees (particularly at tributary junctions and headwater drainages) would help to maintain microhabitats. Olson says few adverse effects to amphibian populations have been reported in thinned forests, whereas clearcutting has negatively affected amphibians in some studies.

Outputs from Burnett's debris flow model can be used to design alternative headwater management scenarios based on the acceptable level of risk. "If a very low level of risk is acceptable, then a hands-off approach may be called for," says Burnett. "If you're interested in assuming a little more risk, then protection can be targeted on those headwater areas that have the highest likelihood of initiating and transporting a debris flow."

Hundreds of rare species, understudied species, and species with low dispersal capabilities (such as mollusks, lichens, and bryophytes) populate Pacific Northwest forests. Headwater linkage areas would provide a web of connections that could benefit this entire forest community. However, how much connectivity is necessary is unknown, even for species that have been studied the most. For this reason, Olson and Burnett suggest an initial "more-is-better" approach when designing links across landscapes.

"We offer a conceptual model that outlines a process you can go through and what considerations you would put into this process to select linkage areas," says Olson. Burnett and Olson anticipate that their basic design will be adapted as additional concerns, such as species needs, ecological processes, or the human dimension, are brought to the table.

"The chain of destiny can only be grasped one link at a time."
—Sir Winston Churchill



Loretta Ellenberg

Ensatina (above) and clouded salamanders are associated with down wood and are often found in headwater drainages of the Oregon Coast Range and western Cascade Range. Linkage areas with down wood may aid their dispersal across ridgelines.

WRITER'S PROFILE

Marie Oliver is a science writer based in Philomath, Oregon.

FOR FURTHER READING

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SCIENTIST PROFILES

KELLY BURNETT is a research fish biologist with the Land and Watershed Management Program at the PNW Research Station. She has been with the station since 1988. Burnett received M.S. and Ph.D. degrees in fisheries science from Oregon State University and B.S. degrees in biology and chemistry from Berry College. Her current research focuses on classifying streams and watersheds, modeling the effects of disturbance on salmon and their habitats, and studying relationships between land management and stream ecosystems.

DEANNA OLSON is a research ecologist and team leader with the Land and Watershed Management Program at the PNW Research Station. She has a Ph.D. in zoology from Oregon State University and a B.A. in biology from the University of California at San Diego. Her research is largely focused on the ecology of aquatic/riparian-dependent animals such as amphibians, with specific emphasis on examining the effects of forest management practices. Recent work includes developing guideline for rare species conservation.

Burnett and Olson can be reached at:

Pacific Northwest Research Station/
USDA Forest Service
Forestry Sciences Laboratory
3200 SW Jefferson Way
Corvallis, OR 97331

Burnett:
Phone: (541) 750-7309
E-mail: kmburnett@fs.fed.us

Olson:
Phone: (541) 750-7373
E-mail: dedeolson@fs.fed.us

COOPERATORS

Bureau of Land Management, Oregon office

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