

Science

FINDINGS

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“Science affects the way we think together.”
Lewis Thomas

Time Tells the Story: Concerns for Long-term Species Resilience with Habitat Changes



Coastal giant salamanders (*Dicamptodon tenebrosus*) breed and spend the first part of their lives in streams throughout Pacific Northwest forests. Photo by Christopher Cousins, Oregon State University.

*“There are no secrets
 that time does not reveal.”*

—Jean Racine, French playwright

The lifespan of creatures in Pacific Northwest forests have a huge range. Mayflies live a mere 24 hours after nymph emergence. Salmon live four to five years on average. Whitetail deer, about six years. Cutthroat trout, about a decade.

And then there’s the coastal giant salamander (*Dicamptodon tenebrosus*), an amphibian that could easily live more than 25 years, if it is able to dodge predators. Not only do these

salamanders live a long time, but amphibians as a group have been around for hundreds of millions of years, making them among the oldest terrestrial vertebrates on Earth. As a class, they’ve survived countless past changes, and yet today, more than 40 percent of the world’s amphibians are ranked as threatened.

Their long lifespans can make it challenging to determine the reasons for their decline. General guidance for understanding population trends is to examine species for at least one generation. Disturbances such as logging and fire can take a long time to show measurable effects on salamander populations. The same goes for forest management methods intended

IN SUMMARY

Coastal giant salamanders (*Dicamptodon tenebrosus*) have lived in forests of the Pacific Northwest for tens of thousands of years. Their survivability is a testament to their ability to withstand and adapt to long-term changes. But can they withstand a succession of more rapid changes resulting from human intrusion and compounded by climate change?

Dede Olson, a scientist with the USDA Forest Service Pacific Northwest Research Station, has studied the intersection of salamanders and forest management practices for more than 30 years. She recently conducted studies of how the management of riparian buffer zones affects salamander populations and the food webs that sustain them.

Coastal giant salamanders can live for more than 25 years. Factoring in their longevity when managing their habitat is key to their survival.

Although some experimental forest treatments can lead to observable responses in fish populations in adjacent streams in just a couple of years, it can take decades for effects on salamander populations to become apparent because their habitat spans streams to ridgelines.

This time lag presents habitat management challenges. Forest managers generally use riparian buffers to protect aquatic and riparian biodiversity in the Northwest; these findings indicate that rather than universal applications of fixed-width buffers, a portfolio of options considering different habitats that amphibians need throughout their long lives may be more effective.



▲ *Oregon ensatina* (*Ensatina eschscholtzii*). Photo by Matt Kluber, Green Diamond Resource Company.

◀ Scientists used boards to cover parts of the forest floor, providing refuge for salamanders, such as the *Oregon ensatina* (above) and alleviating the need to move logs to observe them. USDA Forest Service photo.

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to enhance aquatic life, such as creating buffer zones next to streams and periodically thinning them to let in more sunlight.

Dede Olson, a research ecologist with the USDA Forest Service Pacific Northwest Research Station, recently conducted several studies on forest amphibians and fish that all point to the importance of time to accurately gauge the effects of habitat disturbances. Her findings support conservation planning and long-term monitoring to understand risks to sensitive species.

The Amphibian Life Cycle

“Forest amphibians, relative to other animals, age slowly and live a long time,” Olson says. “That’s particularly true of salamanders. We hear a lot about old-growth forests. Well, these are old-growth amphibians. Some may live over 25 years and perhaps longer, into their third or fourth decade.”

For some forest amphibians, life begins in streams, where adults lay their eggs. In the case of coastal giant salamanders, larvae from those eggs stay in the streams for upwards of four years before they metamorphize into adult form.

This long maturity process can aid in their species’ persistence. During their waterborne stage, if there is a disturbance in the forest—a fire, for example—aquatic life stages may weather that disturbance as long as the stream remains habitable.

“It’s like a bank account, or a diverse investment strategy,” Olson says, explaining how salamanders may survive over the long haul despite the ups and downs of the different environments used by single life stages.

Their slow aging can give salamanders a survival edge throughout their lives. Consider the bell-shaped curve of human life expectancy: the curve forms a steep, diminishing tail after about age 70 as humans succumb to a host of age-related maladies. That curve doesn’t exist for salamanders; it’s more like a straight horizontal line that extends from the peak of adulthood. The fact that they are cold blooded helps in their slow aging process.

“They don’t get old, so to speak” Olson says. “Once these amphibians live to adulthood, their chance of living on is somewhat constant. They can regenerate toes, tails, legs ... they just keep going. The chance of predation is greater than dying of old age.”

The Oregon ensatina can live for more than 10 years with negligible aging. Salamander defenses include self-amputating their tails to distract predators and secreting unpalatable skin chemicals. Photo by Matt Kluber, Green Diamond Resource Company.



Forest Service



Humans can learn a lot from them. “They’re like a little gold mine,” she says. “If we can crack that longevity code, there could be a lot of benefits to the human population as well as at-risk animal populations.”

But being long lived with slow aging isn’t always a foolproof strategy. It works well in the face of isolated environmental disturbances that don’t last particularly long. It does not work well when faced with chains of severe disturbances that happen in rapid succession.

In that scenario, the life plan of a species like the Pacific treefrog (*Pseudacris regilla*), for example, is more advantageous. These relatively short-lived amphibians live in ponds and readily disperse. If their pond becomes crowded or dries up, they can move to another one. This makes them hardy survivors even in urban areas where rapid habitat changes may occur.

“A treefrog can breed in a flooded meadow or roadside ditch, which can dry out after spring rains stop. Yet their eggs and larvae develop really fast, producing little frogs in a couple of months, and some first-year froglets become breeding adults the next year. And those little frogs can hop out and find other habitats. This life plan contrasts sharply with that of a giant salamander,” Olson says. “It’s like a tortoise and hare tale, with each having different assets to survive, depending upon the context.”

This is the critical point in Olson’s recent research on the interplay between forest management and salamander survival. Accurately assessing how various forest management techniques—for example, the creation of streamside buffer zones—can affect salamanders can take years or decades.

The Case for Longer Timelines

The effects of forest management on some fish and amphibians may become apparent after a year or two of observation. It appears that understanding salamander responses simply requires more time. Given their long lives and slow aging, it can take years of monitoring before it’s possible to determine which factors help or hurt salamander populations.

Take riparian thinning, for example. Resource managers thin streamside forests for several reasons, including protecting and restoring sites and enhancing productivity. Thinning allows more sunlight to reach the stream and surrounding banks, promoting the growth of plants and organisms that fish and amphibians can feed on.

But those goals depend on complex food web dynamics.

KEY FINDINGS

- Many cold-blooded (ectothermic) vertebrates—including some forest amphibians in the Pacific Northwest—have relatively slow aging rates and greater longevity compared with warm-blooded vertebrates. This may enhance their adaptive capacity when faced with some temporary or slowly occurring environmental stressors, but they can become vulnerable when faced with rapid ecological changes.
- Genetic research has found that some populations of coastal giant salamanders (*Dicamptodon tenebrosus*) have less genetic variation than other populations. Reduced genetic variation could make these populations more vulnerable to changing environmental conditions.
- Because of their complex life history with both aquatic and terrestrial phases, and being long lived, the effects of forest management on amphibians can take years to manifest. Studies in western Oregon found it took 10 years before changes could be detected in population densities of stream amphibians after forest thinning and implementing various streamside buffer configurations.
- In western Oregon, 28 years (1994–2022) after initial treatment, wider streamside buffers were found to be more beneficial to fish and amphibian populations than narrower buffers.



View looking into a streamside riparian buffer from an upland forest that has undergone two sequential thinning treatments. USDA Forest Service photo by Dede Olson.

To evaluate how thinning influences stream food webs, Olson partnered with David Roon from Oregon State University and other scientists from universities, the Forest Service, and the U.S. Geological Survey to implement field experiments in second-growth redwood forests in California. They tracked what happened to the food webs a year before and a year after streamside riparian-forest thinning treatments.

As expected, the thinning treatments increased light to the stream channel, but the effects on food web components were mixed. In fact, there was no evidence that thinning increased prey abundance for any of the top

predators in the area, including coastal giant salamanders.

This suggested to the researchers that riparian thinning doesn’t necessarily enhance aquatic productivity in forested streams. It may have some role to play, but other factors need to be considered.

However, these were short-term results—the observable effects on prey biomass one year after treatment. It is possible that a single year is not enough time for the community to respond. The researchers concluded that more time is likely needed to fully observe the complexities that make up the multi-tiered food webs of forest streams.

Buffering for Protection

Given what is known about amphibian life cycles and their habitat needs, Olson suggests a more dynamic and flexible approach to long-established “best practices” for managing riparian zones—the vegetated areas bordering streams. Current best practices, for example, may prescribe the same riparian zone standards across entire states, with limited information on specific sites. She suggests a more nuanced approach that considers smaller scale conditions.

Establishing and maintaining riparian buffer zones are forest management practices that began decades ago. They were set up initially to protect water quality, but the overall effects of buffer zones go well beyond providing clean, cool water. Buffer zones help maintain coarse stream substrates and down wood

where fish and amphibians lay their eggs, hide from predators, and find refuge during unfavorable conditions.

Olson’s studies on the various effects that riparian buffer zones have on amphibian and fish life in the Oregon Coast and Cascade Ranges have been ongoing since 1994. She is focusing on 58 stream reaches as part of a field experiment of riparian forest thinning with different streamside buffer widths.

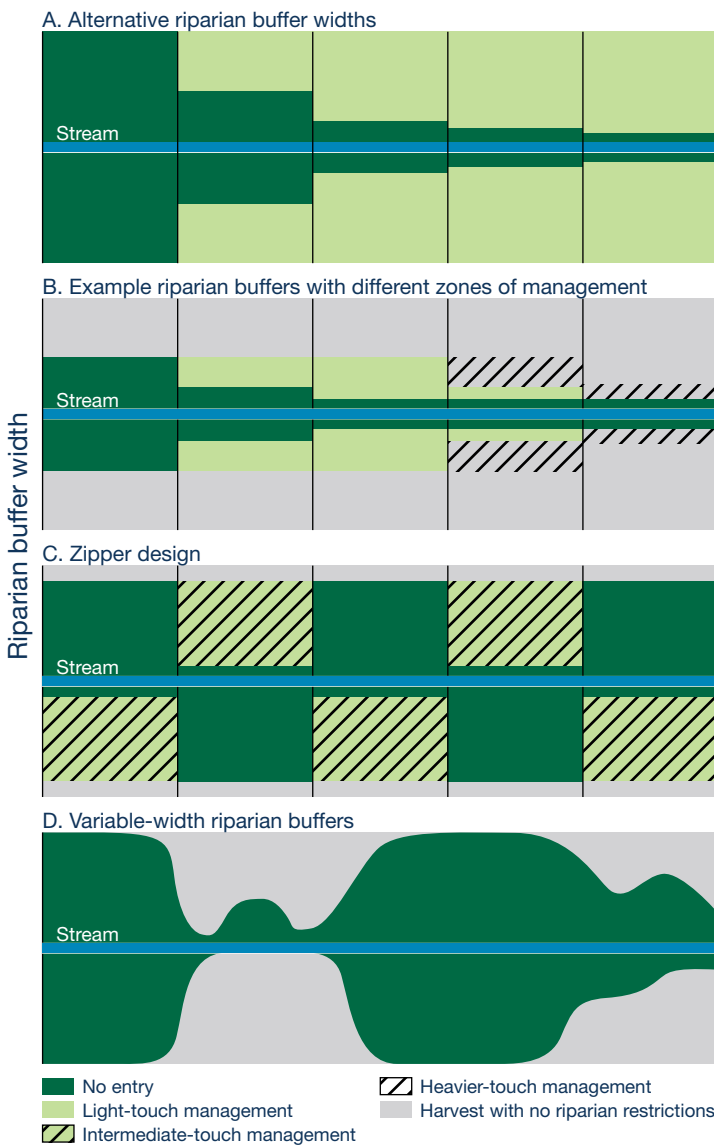
She found that it took 10 years after thinning before some of the initial effects on salamander population densities became evident. This lag time could point to the need to factor in the lifespan of the organisms when designing studies to assess the effects of changes to their habitat.

These same sites were thinned a second time, 10 years after the initial treatment.

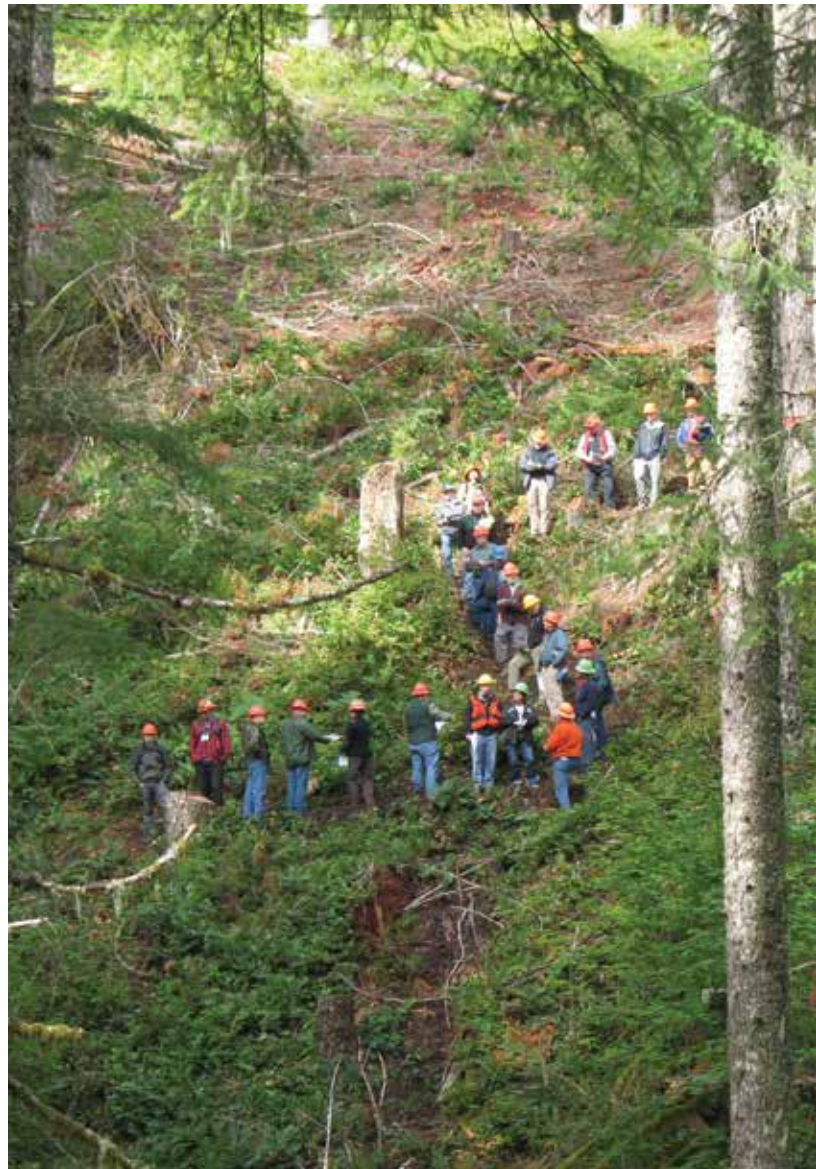
One year after that second thinning, the researchers found that the population densities of all surveyed species remained the same in sites where the streamside buffers were 15 m or greater. In 2022, 5 years after a second thinning, the researchers found significantly higher densities of sculpins, torrent salamanders (*Rhyacotriton* spp.), and coastal giant salamanders in headwater stream reaches with 70-m buffers extending laterally from both banks than in streams with narrower buffers.

The timing factor is consistent with that “one-generation rule,” where you need to study animal systems for at least a generation to understand population trends.

Olson’s findings about amphibians and buffer zones are just as applicable on private forest lands as they are on federally managed forest.



Four different riparian configurations that may go beyond best management practices to better protect or restore aquatic and riparian ecological conditions, functions, and processes, and promote heterogeneity across watersheds and landscapes.



View across an incised headwater stream with an uncut riparian buffer showing the upland timber harvest zone in western Oregon. USDA Forest Service photo by Dede Olson.

She has partnered with colleagues focusing on private land management to provide information to guide stream-riparian management.

“Sustainability is one of our core values, and we use science to guide what we do,” says Jessica Homyack, a wildlife biologist and director of Environmental Research and Operational Support at Weyerhaeuser.

Homyack, Olson, and Ashley Coble of NCASI (National Council for Air and Stream Improvement, Inc.) coauthored a paper for an American Fisheries Society symposium that highlighted potential benefits of greater flexibility when establishing riparian buffer zones. More flexibility, Homyack says, allows for case-by-case determinations of the best ways to protect streams and the fish and amphibians that live in them.

Establishing Connection

Adequately sized stream buffers are an important factor in maintaining the health of fish and amphibian populations but so is the concept of connectivity, that is, finding ways to allow these creatures to connect with other streams and other forests, allowing them to mobilize and spread out. Whether that comes in the form of removing natural and human-made barriers, or actually creating new corridors, it enables aquatic and terrestrial wildlife to find new spawning areas, feeding grounds, and refuges in case their native habitat suffers ecological damage.

It also gives them more mating possibilities. Olson says maintaining connectivity is essential for maintaining their genetic diversity—an important survival factor.

Olson and fellow researchers conducted a study, beginning in 2010, in which they examined DNA samples from 318 individual giant salamanders across 23 headwater sites in the Oregon Coast Range. Their sampled sites were spread across a latitudinal gradient. They were often in adjacent watersheds and had undergone various disturbances over the last 70 years, including fire and logging. The goal was to evaluate if those conditions were associated with patterns of genetic diversity.

Their results were puzzling. First, they found that while certain populations of coastal giant salamanders had the opportunity and freedom to connect with other populations, some populations had low genetic variation, suggesting that they were not connected to neighboring sites. Despite apparent connectivity across the region, there seemed

LAND MANAGEMENT IMPLICATIONS

- Slow aging, greater longevity, slow dispersal, and low genetic variation are traits of Northwest forest amphibians that may interact to affect their ecological resilience to relatively rapid habitat changes from land use or climate change. For these amphibians to persist despite these changes, they need access to various habitat refuges specific to their different life stages.
- Watershed-scale planning is key to retaining the diversity of forest habitats needed for amphibian breeding, foraging, and dispersal across aquatic and terrestrial sites. Factoring in longer timeframes to account for amphibian generation times appears critical to understanding species' risks and persistence patterns and for efficiently conserving their aquatic and upland forest habitats.

to be local genetic bottlenecks that were not easily explained by any disturbances.

Second, there was less genetic variation in the northernmost-sampled salamander populations in the Oregon Coast Range, suggesting that animals were not freely mixing across their latitudinal range.

“Although we don’t know the exact mechanism behind this pattern, we do know that these salamander populations moved north with the retreat of glaciers from the last ice age,” Olson says. “Could they still be chasing glacial retreat?”

Salamanders establishing new sites as they moved north with the glaciers could have reduced genetic variation, a founder effect, she explains. Alternatively, later population declines could result in genetic bottlenecks within established populations.

“Although giant salamanders have not been identified as being an at-risk species, this lack of genetic diversity is at odds with a robust species, possibly placing them in a precarious situation for dealing with future perturbations such as climate change and diseases,” Olson says.

According to Olson, the low genetic diversity is a cause for concern, but it doesn’t point to any obvious solutions. It does, however, reinforce the need for basic conservation practices, such as managing lands in ways that support population breeding and maintaining the integrity of their habitat, including connectivity corridors between watersheds—maintaining gene flow can retain genetic diversity.

Putting all these pieces together—slow aging, longevity, complex life history with use of aquatic and upland habitats, unexpected genetic variation—illustrates the complexity of the natural world. It also points to the need for time when it comes to making decisions that affect a broad range of wildlife species.

*“Time is the school in which we learn,
time is the fire in which we burn.”*

—Delmore Schwartz, American poet

For Further Reading

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Writer’s Profile

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Scientist Profile



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