WILDLIFE

IN MANAGED FORESTS

Stream-Associated Amphibians

Wildlife in Oregon's Managed Forests
Outreach Project Overview

A great deal of research has been done by public and private organizations regarding wildlife and wildlife habitats in Northwest managed forests (i.e., forests where management such as thinning, harvesting, prescribed burning, tree planting and vegetation control is practiced). However, the research results and their implications have not been communicated in an accessible, systematic fashion. This publication is part of a series from the Oregon Forest Resources Institute. The Wildlife in Managed Forests Outreach Project aims to synthesize current research findings and make information available to field practitioners in forest and wildlife management, and to other interested stakeholders such as conservation organizations, regulators and policy makers. In addition to publications, information will be disseminated through workshops, tours and conferences.

Project Partners include:

- Defenders of Wildlife
- National Council for Air & Stream Improvement
- Oregon Department of Fish & Wildlife
- Oregon Department of Forestry
- Oregon Forest Resources Institute
- Oregon State University College of Forestry
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STREAM-ASSOCIATED AMPHIBIANS

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New Research Informs the Conversation About Environmental Protection

Introduction

Many of the 47 species of amphibians — frogs, toads, salamanders and newts — that are native to the Pacific Northwest have some kind of association with freshwater streams. This is not surprising since amphibians are, after all, water animals by definition. Their name — "amphi-," meaning "double," and "bio," meaning "life" — tells this story. Many amphibian species breed in water and then metamorphose to a terrestrial (earth-associated) form, although there are significant exceptions.

One-quarter of the region's amphibian species depend on headwater streams and their riparian environments for breeding and rearing habitat, cover, food or all three. In the Northwest, most streams originate in forests. Because these forests are economically, socially and environmentally important, amphibians and their needs hold particular interest for forest managers and for society at large.

While fish (notably, salmonids) and birds (the northern spotted owl and marbled murrelet in particular) have been visibly at the center of the Northwest's forest-conservation debates, amphibians also play important and distinctive roles in forest ecosystems (Pilliod and Wind, 2008). They span aquatic and terrestrial habitats upstream and downstream and across the stream channel. They are also linked across food webs as both predators and prey.

Amphibians play important roles in forest ecosystems.

Like salmon and many other native wildlife species, amphibians are sensitive to changes in their forest habitat. While none of the Northwest's native amphibian species is on the federal endangered or threatened list, about half of them are of conservation concern to at least one state or federal regulatory agency.

Harvesting trees, building roads and other activities of contemporary forest management cause disturbances to the landscape and these changes are widely believed to affect amphibian habitat, at least temporarily. However, the magnitude of these effects is hard to pin down and the long-term, cumulative effects are largely unknown. There are many factors to consider. The geology and forest type of a given area, its latitude and elevation, slope steepness and aspect, proximity to water, stream temperature and relative humidity all bear on how — and how much — the varying types of forest management affect amphibian habitat.

Recent science is adding more depth and detail to the body of knowledge about amphibian responses to forest management. Scientists are learning more about the importance of smaller habitat features such as substrate (whether gravel, cobble or boulders); microclimate; relationships with predators, prey and competitors upstream, downstream and across the channel profile; patterns of movement within and across stream channels; and resiliency to disturbances.

While it is too early to generalize, the accruing knowledge is painting a more detailed picture of the responses of stream-associated amphibians to forest management. As the picture becomes clearer, the research promises to help forest managers hone their practices to make them more precise and effective in protecting amphibian habitat on forested lands.

Here a few caveats are appropriate. This paper was sparked by a February 2009 symposium of scientists, including some amphibian experts. It summarizes the published and ongoing work presented at that gathering, along with other selected studies. We offer this sampling of current research to illuminate the discussion about appropriate protection strategies for amphibians in commercially managed forests. The reader is cautioned that this summary is by no means a complete bibliography, nor is it intended as a management handbook. It addresses a narrow topic — amphibian habitat in present-day managed forests west of the Cascades crest — without much reference to the larger scientific or social context. This means that unfolding dynamics such as federal forest policy, climate change, invasive species and amphibian decline due to other environmental factors (e.g., ozone depletion, water pollution, diseases or parasites) are beyond its scope. Our observations are aimed at forest managers, wildlife biologists and policymakers. The observations are intended as suggestions only and offered in the hope of informing a broader conversation. Interested readers are urged to explore the literature listed in the bibliography.

Amphibians are linked across food webs as both predators and prey.

AMPHIBIANS AND TIMBER HARVEST

Recent research on amphibian responses to forest management began in the 1980s, after a century of timber harvest had converted much of the Northwest's presettlement forest to natural second-growth stands and plantation forests. Biologists were becoming increasingly concerned about the environmental effects of the forest practices of the day on fish and other forest-associated wildlife.

Stream-associated amphibians thrive in cool, moist environments. They do not tolerate temperature change well, and they require stream environments relatively free of silt (Pilliod and Wind, 2008), which can fill in the spaces between rocks and cobble that the animals need for cover (Stoddard and Hayes, 2004).

Historical forest management practices that involved harvesting trees to the stream's edge failed to stop silt runoff from logging roads, and that left forest renewal to chance, which likely had adverse effects on local amphibian populations.

Headwater streams are important habitat for amphibians.

The first links between logging and amphibian well-being were made in the 1920s, when Helen Gage, a University of Michigan biologist working on the life history of tailed frogs, observed that the frogs were present in unlogged forests near Lake Cushman on the east side of Washington's Olympic Peninsula, but absent from the logged areas (Hayes, personal communication). This was at a time when there were no laws that protected watersheds or wildlife, and mountain streams were commonly used as yarding corridors or log flumes.

Gage's observations were affirmed by Gladwyn Kingsley Noble, a behaviorist from the American Museum of Natural History who also studied the ecology of tailed frogs. Based on these and subsequent observations, it seemed logical to assume that logging had caused the decline in frog populations, even though no prior work had been done to determine how many frogs were present before logging and where they were living.

In 1968, a master's thesis by R. Bruce Bury on the distribution of tailed frogs in northern California's redwood belt reported that frogs seemed to be disappearing from logged areas. He observed that frogs in forests nearest the coast seemed to fare better than those farther inland. Bury went on to become a leading researcher on the effects of logging on stream-associated amphibians. His studies and others, including Murphy and Hall (1981), Hawkins and others (1983), Bury (1988), Bury and Corn (1988), Corn and Bury (1989), and Dupuis and Steventon (1999), concluded that intensive forest management was reducing the abundance of stream-associated amphibians — especially tailed frogs and torrent salamanders — by raising stream temperature and increasing the amount of sediment in streambed gravel.

Current research practice using blocknets and rubble rousing.

In the meantime, current management and regulatory approaches were being formulated for protecting riparian habitat in Northwest forests. The approach adopted in the 1994 Northwest Forest Plan for federal forests requires extensive no-cut buffers along perennial fish-bearing streams (Olson and others, 2007). State forest practices rules for private lands in Oregon, Washington and California require landowners to maintain narrower forested buffers along most fish-bearing and some non-fish-bearing stream reaches. The rules also exclude harvest machinery or require lighter-touch harvesting in certain areas on private lands.

These measures are not specifically targeted at protecting amphibian habitat. Their primary intent is to protect fish and that is why the rules mostly apply only to fish-bearing reaches. Until recently it has been assumed that what is good for fish is also good for amphibians, however, current research is taking another look at that assumption.

Amphibians have some of the same in-stream habitat requirements as fish, and they have additional needs on land. Recent findings suggest that current riparian-area protection policies on public and private lands may benefit from a discussion about the specific needs of amphibians. While the work is far from conclusive, some recent studies open the possibility that current riparian rules may be overly restrictive in some parts of the landscape and provide too little protection in others.

For example, scientists are finding that non-fish-bearing or seasonal headwater streams are more important habitat for amphibians than was previously recognized, yet current riparian rules allow harvest in these areas (Olson and others 2007). Oregon, Washington and California all restrict management within the riparian zone, but non-fish-bearing streams do not receive the same protection as fish-bearing streams.

Some findings suggest that it might be possible to tailor buffer protections to habitat needs of different amphibian species in different parts of the landscape. For example, scientists are exploring the smaller habitat features of riparian areas that may be critical from an amphibian perspective, such as air temperature, relative humidity, steepness of valley walls and character of the rocky substrate. They are learning that these microsite characteristics, as they are called, may sometimes be more important to salamander habitat than the presence of forest next to the water (McIntyre, 2003, and McIntyre and others, 2006).

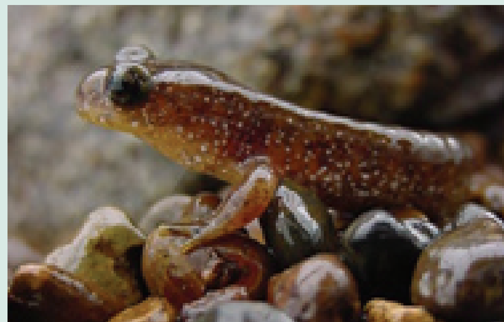
While it may be too early to start rewriting rules about amphibian protection, it seems reasonable to expect that, as the research unfolds, more targeted and site-specific measures might be devised. The objective would be to protect amphibians as well as, or better than, current widespread buffer requirements and harvest restrictions, while allowing landowners to manage their operations more cost-effectively and with greater confidence that their conservation efforts actually work.

Some key Northwest stream-associated amphibian species

Cascade torrent

Columbia torrent

Olympic torrent



Southern torrent

Torrent salamanders

Cascade torrent salamander *(Rhyacotriton cascadae)*
Columbia torrent salamander *(Rhyacotriton kezeri)*
Olympic torrent salamander *(Rhyacotriton olympicus)*
Southern torrent salamander *(Rhyacotriton variegatus)*

Size: Torrent salamanders are small, usually 3-4.5 inches (8-11 centimeters), with short snouts and large eyes. Larvae have small external gills that they lose at metamorphosis.

Diet: They primarily eat insects, especially larvae and other invertebrates.

Habitat: Torrent salamanders are stream obligates and require small streams for breeding, rearing and foraging. Preferred habitat is in and near cold, clear streams flowing through moist coniferous forests. Torrent salamanders are often found under the gravel along the edges of a stream and in the spray zones of waterfalls.

Range: The different species can be hard to tell apart, but they apparently do not overlap in range.

- Cascade torrent salamanders occur in the Cascade Range of southern Washington and northern Oregon.
- Columbia torrent salamanders occur in southwestern Washington and northwestern Oregon.
- Olympic torrent salamanders occur in the Olympic Mountains.
- Southern torrent salamanders occur from central Oregon to northern California, primarily in forests in the Coast Range.

Did you know… Adult torrent salamanders breathe mostly through their skin.

NEW THEMES EMERGE AT SYMPOSIUM

A symposium[1] held at an annual scientific conference in early 2009 drew researchers from the forest industry, universities and land management agencies to talk about recent findings on forestry and management practices and their effects on amphibians. Several themes are emerging from work presented at the symposium and related studies (see especially Olson and others, 2007, and Kroll, 2009). These themes include the importance of microsite characteristics, the role of connective corridors in headwater streams, new findings on the duration of forest-management impacts, the efficacy of streamside buffers and efforts to make research methods more reliable.

Forest cover may not always be the most important habitat variable.

Importance of microsites

The character of the small riparian areas where salamanders and frogs live, eat, hide and breed is more important than was previously known. Stream temperature, humidity, character of the substrate (size of the rocky pieces and the parent material from which rock and soil derive), presence of wood and moss on the ground and presence of a dry-to-wet gradient of hiding places all are site characteristics that can be critically important to amphibian habitat in managed forests.

Such site characteristics vary widely in different streams; different reaches within a stream; different slopes, aspects and elevations; and landscapes with diverse geologies and management histories. Some studies indicate that, in some circumstances, the site features may be more important to certain amphibians than the width of a streamside buffer.

Forest Service Researcher Deanna Olson and colleague David Rundio looked at the effects of three different buffer widths and upslope thinning operations on three species of terrestrial salamanders near two headwater streams in managed forest stands (Rundio and Olson, 2007). Two of the salamander species (Ensatina and Oregon slender salamander), both of which spend their lives on land but need riparian areas for breeding and

[1] Joint annual meeting of the Society for Northwestern Vertebrate Biology and the Washington Chapter of the Wildlife Society, Skamania Lodge, Stevenson, WA, Feb. 18-21, 2009.

Giant salamanders
Cope's giant salamander *(Dicamptodon copei)*
Coastal giant salamander *(Dicamptodon tenebrosus)*


Cope's giant salamander

Size: Cope's giant are medium to large salamander (20 centimeters) with short gills and small, mottled yellowish markings all over their bodies. The coastal giant salamanders are larger than the Cope's, (35 centimeters) and have marbled brown and black patterns all over their bodies.

Diet: Because they grow to a large size, the salamander larvae feed on larger prey including small fish and the larvae of mole salamanders. Small adult giant salamanders eat land-dwelling invertebrates, which they catch with their long, fast tongues. As they grow larger, they prey on vertebrates, such as slender salamanders, lizards, shrews, mice, and even snakes, which they seize with their strong jaws.

Habitat: Giant salamanders are stream obligates, requiring streams for breeding, rearing and foraging. Their preferred habitat is in and near cold, clear, fast-flowing streams in moist coniferous or mixed coniferous-deciduous forests.

Range: Cope's giant salamanders occur in the Olympics, Washington Cascades, Willapa Hills of southwestern Washington and northwestern Oregon. The coastal giant salamanders are common in both states and occur in the Washington and Oregon Cascades, Willapa Hills and the coastal mountains of Oregon and California.

Did you know… Cope's giant salamanders are usually neotenic — that is, they mature and reproduce in the larval form without metamorphosing into terrestrial adults, although some do undergo metamorphosis.

foraging, did not seem to be affected by the thinning as long as there was plenty of dead wood on the site, even if the stream buffer was narrow. The researchers concluded that the quantity of downed wood along with other microsite characteristics might make more of a difference in protecting these terrestrial species than the width of the buffer.

Another symposium presenter, Aimee McIntyre of the Washington Department of Fish and Wildlife, spoke about her study of Van Dyke's salamanders along headwater streams and seeps in Washington's Cascade Range (McIntyre, 2003, and McIntyre and others, 2006). With colleagues from Oregon State University and the U.S. Forest Service, McIntyre surveyed the salamanders, noting the habitat characteristics at each site, such as the amount of vegetative cover, size of rocky substrates, gradient, forest type and steepness of valley walls and rocky seep faces.

The Van Dyke's salamander is a terrestrial species; it breeds on land, but it requires riparian habitat. The researchers found that the probability of finding Van Dyke's salamanders on a given site increased at sites with exposed bedrock, small cobble, steep valley walls and seep faces, and early-seral vegetation, as well as a gradient of conditions from wet to dry and enough water to keep the microsite cool and moist.

A lack of overstory tree cover or early-seral vegetation was among the most strongly associated characteristics. McIntyre and her colleagues reasoned that the geomorphology of some seep sites — the bedrock substrate and steep valley walls — provided the needed shelter and protection from sunlight, possibly superseding the need for a forest overstory as long as the microsite conditions were met. In any case, a rocky seep is usually not a hospitable site for establishment of trees.

Spatial scale is important to keep in mind when interpreting these results, McIntyre says. The study plots were small compared to the overall forested landscape, and relationships with the larger matrix of forest were not the focus of the study. Even so, forest cover does not always seem to be the governing variable for good habitat, at least for this species at these particular sites.

Coastal giant salamander (Dicampton tenebrosus)

Role of connective corridors

Another theme that emerges from current research is the importance of connectivity across headwaters. The upstream and downstream linkages among amphibians and their competitors, predators and prey are highly important, but so are the relationships that link amphibian habitat with the larger upslope landscape. Where amphibians and fish live in the same stream reach, according to Deanna Olson, they interact "as part of cascading trophic networks" along the stream (Olson and others, 2007). "Trophic" means having to do with food or nutrition and "network" means web. Because amphibians move laterally in a way that fish cannot, they are also part of a crosswise food web linking terrestrial nutrients, predators and prey.

As yet, little is known about that network, but the research suggests that upland areas may represent more important habitat for amphibians than was previously appreciated (Olson and Burnett, 2009). Several studies have found stream-associated amphibians as far as 100 meters away from a stream, which suggests that they regularly travel overland, presumably crossing ridgelines and entering neighboring watersheds in headwater areas and potentially help to maintain gene flow at the landscape scale.


Dunn's


Larch mountain


Van Dyke's


Western red-backed

Plethodon salamanders
Dunn's Salamander (Plethodon dunni)
Larch Mountain salamander *(Plethodon larselli)*
Van Dyke's salamander *(Plethodon vandykei)*
Western red-backed salamander *(Plethodon vehiculum)*

Plethodon species are part of a larger group of lungless salamanders that breathe through their skins. Unlike most other amphibians, they grow directly to adults without undergoing an aquatic larval stage.

Dunn salamanders are brown and usually have a yellow or tan stripe down their backs. They occur west of the Cascade Range from southwestern Washington to California. They are common along stream banks and may be found upslope in forested riparian zones.

Larch Mountain salamanders have a brown back, red or pink belly and small white flecks on their sides. They occur in the Cascade Mountains of southern Washington and northern Oregon. Their preferred habitat is shady, cool rock outcrops and talus slopes, although they are also found in moist coniferous and mixed forests. They are active during spring and fall and bury themselves in the talus during summer and winter.

Van Dyke's salamanders may be yellow-orange, rose-pink or black with a yellow stripes. They occur only in Washington, in the Olympic Mountains, southern Washington Cascades and Willapa Hills. Their preferred habitat is in and near small streams, springs and seeps in moist coniferous forests. They lay eggs inside large decaying logs.

Western red-backed salamanders are brown with broad reddish or yellow stripes down their backs. They occur west of the Cascades from British Columbia to southern Oregon. They are terrestrial, with preferred habitat in moist coniferous or mixed forests.

Duration of harvest impacts

A third emerging theme is that, in general, impacts from forest harvesting may be shorter lived than previously believed. Studies conducted two years after upslope forest operations in the Northwest and elsewhere documented negative effects on amphibians, even in cases where buffers were in place. However, a team led by Forest Service Research Scientist Matthew Kluber found that these early negative effects may dissipate within a relatively short time when buffers are present (Kluber and others, 2008). Five and six years after upslope areas in western Oregon were thinned, the researchers surveyed for amphibians along perennial non-fish-bearing streams in western Oregon. The streams had buffers that ranged from 6 meters to more than 15 meters wide. The researchers found no significant differences in numbers of amphibians between the treated areas and the untreated control areas.

This study, like most amphibian studies to date, is limited by a small number of sites and few replications, and therefore, say the researchers, its findings should be extrapolated cautiously. They point out that the two most abundant salamanders they captured, the western red-backed salamander and Ensatina salamander, are also the two most common terrestrial salamanders in the Northwest. Their findings revealed little about the habitat needs of rarer, more vulnerable and highly stream-associated species such as tailed frogs (of which six were captured), and southern torrent salamanders (of which only one was captured).

"We suggest that the failure to detect statistically significant differences in amphibian captures between buffer treatments does not detract from the importance of maintaining intact riparian corridors along headwater streams," the authors wrote. They speculate that a moderate thinning — coupled with buffers in areas that include such habitat features as rocky outcrops, seeps and down wood — might pose no harm to amphibians but, like many scientists, they are careful to hedge their speculations with a host of qualifications.

This topic needs further work, according to Weyerhaeuser Biologist A.J. Kroll. In a 2009 paper, Kroll examined some problems with drawing valid inferences from available research about the long-term effects of forest harvesting. Most of the amphibian studies to date have been short-duration surveys conducted at the stream-reach scale on lands with a history of logging. Many of these are retrospective studies, which use current conditions to assess what happened in the past. Such studies can yield valuable information, but they do not compare conditions before and after a controlled experiment. The few experimental studies that exist have been hampered by the challenges of rigorously replicating treatments across a heterogeneous landscape, and of finding relevant control areas with all the essential attributes of the treatment areas.

No studies have compared amphibian presence and abundance before and after harvesting of an old-growth stand — an opportunity that is unlikely to occur given the current rarity of old-growth harvest operations. And few studies have yet examined amphibian populations at scales larger than a watershed or longer than a decade. However, two ongoing projects — a large-scale, replicated experiment in Washington and two paired-watershed experiments in Oregon — promise to help fill that gap (please see sidebars).


Researchers are exploring the potential benefits of a more open canopy for amphibians.

Efficacy of buffers

Some research suggests that buffers over headwater streams might limit stream productivity and hence food supply for organisms in the buffered reaches and downstream. In preliminary, yet unpublished research, Longview Timberlands Biologists James MacCracken and Jennifer Stebbings studied headwater amphibians for abundance and body condition before and after four levels of canopy openings designed to leave four levels of shade along the stream.

After harvest, they found more giant salamanders and Cascade and Columbia torrent salamanders in streams with the lowest levels of shade retention. Tailed frogs had better body condition in the less shaded areas and growth rates of the salamanders were greatest in the areas with the least shade. In this instance, say the researchers, opening the canopy seems to have had beneficial effects on these amphibian species, probably because it enhanced stream productivity and hence food supply through either more sunlight or warmer temperatures or both. It's important to keep in mind that the forests upslope from this study were left unharvested, and no conclusions can be drawn about the long-term implications of opening the riparian canopy.

Another symposium speaker, John Richardson of the University of British Columbia, presented early findings of his study of coastal giant salamanders and tailed frogs in streams east of Vancouver, B.C., in the Chilliwack River drainage. The streams were in old-growth and second-growth forests and recent clearcuts. He found higher numbers of both amphibian species in the clearcuts. "It was unexpected," he told the workshop audience, "and some people didn't believe it." However, elevation was a confounding factor, since the old-growth forests tended to be at higher elevations.

Richardson also noted that growth and survival at the larval stage in both species are controlled by the productivity of the stream that provides their food. At sites in colder climates, such as those at more northerly latitudes or higher elevations, streams generally stay colder year-round. Richardson's work, like MacCracken's, suggests that stream productivity may be more important for amphibians in these cooler environments than shade over the stream.

These studies and others raise the possibility of tailoring stream buffering to the geography of the site, the species of amphibians being protected and the nature of the management activity upslope. The main functions of buffers along streams are to moderate stream temperatures by providing shade, maintain

Coastal tailed frogs (Ascaphus truei)

Size: Coastal tailed frogs are small (5 centimeters) and have light to dark brown, slightly granular skin. Tailed frogs are skin-breathers, although they do have small lungs.

Diet: They eat insects, snails and other small invertebrates, using a "sit and wait" strategy for hunting. They are not able to grab prey with their sticky tongues as other frogs can -- their tongues are attached closely to the floors of their mouths, so they cannot flip out their tongues to grab insects.

Habitat: Coastal tailed frogs are stream obligates, requiring streams for breeding and rearing. Their preferred habitat is in and near fast-flowing streams in moist coniferous or mixed forests. They are also found in open areas.

Range: Coastal tailed frogs occur in the Cascades and Coast Range from southern Canada to northern California, and in mountainous areas of eastern Oregon and Washington.

Did you know… The "tail," which only males have, is actually a copulatory organ used to fertilize the eggs of the female internally.

other microclimate characteristics and keep silt from entering the water. Buffers are also important sources of organic debris and they help maintain bank stability, minimizing the coarse sediment that washes in from landslides.

Several studies and much unpublished observation suggest that buffers do all these things (Olson and others, 2007). The degree of moderating influence depends on many factors, including steepness of the gradient upslope. Steeper canyon walls may have a greater effect on relative humidity (and perhaps other habitat features) in the riparian zone than the presence of a buffer.

Salamanders are small and elusive, and tend to live in rugged, inaccessible places.

The effectiveness of buffers also depends on the type of forest operation being conducted. U.S. Forest Service Researcher Paul Anderson and others (2007) studied a range of buffers, from 6 meters to 70 meters wide, protecting streams from thinning operations upslope. They found that, with a buffer of at least 15 meters wide, stream temperatures and relative humidity in the riparian area were only minimally affected by upslope thinning. Thus, depending on the degree of tree removal, it is possible that a buffer as narrow as 15 meters could maintain the riparian microclimate. Because optimal riparian habitat consists of a suite of features, it is too early to say how widely applicable this finding may be.

Improving research methods

Another major theme of current amphibian science is the limitations of research methods. Salamanders, newts and frogs are not the easiest wildlife to study. They are small and elusive, and they tend to live in rugged, inaccessible places. They have variable life histories and take different forms at different life stages. Some species look alike but differ in behavior. They can be hard to find, even when you're looking for them with a flashlight. Sometimes they'll be in the water, sometimes buried under cobble along the shore, sometimes curled under a damp log farther up the bank. Some can move faster and farther than others. Many are most active in the evening or at night. All this can make accurate sampling difficult.

Lowell Diller, Green Diamond Resource Company Biologist and a presenter at the wildlife symposium, and his team are in the 12th year of a 50-year research and monitoring project to support an aquatic habitat conservation plan on the company's timberland in northern California. The researchers are examining randomly selected streams in paired sub-basins, those undergoing timber harvest as well as unharvested controls. The species covered by the plan are Chinook and coho salmon, steelhead, cutthroat and rainbow trout, coastal tailed frog and southern torrent salamander.

In his presentation, Diller mentioned the challenge of surveying for amphibians over the long term in a way that yields accurate numbers but doesn't damage habitat. "Our [initial] solution," he told the audience, "was a biennial 'lighter-touch' occupancy survey, but we were concerned about the scope of inference and lack of detection probabilities."

The Green Diamond researchers revised their sampling scheme so that it is less intensive but includes more sites along the stream. The larger sample size is likely to tax the company's research resources, according to Diller. The scientific team consists of him and two other people. They are devising a rolling schedule of sampling visits during five years to keep the surveys both meaningful and cost effective.

Accurately assessing the probability of detecting the species of interest when it is present is a key concern, Diller says. "For instance, we have to think about the differences in habitat as the stream gradient gets steeper, because the detection probabilities change along the reach." To improve confidence in detection probabilities within their study areas, the team conducted a mark-and-recapture study of adult tailed frogs. The study required substantial effort to get a useful estimate, partly because the animals were difficult to locate.

In the study by Kroll and others (2008) mentioned above, researchers used information from their own and previous studies to model the detection probabilities of the amphibians they surveyed. For all species, the model estimated detection probabilities as less than 1, which indicates that a single survey will not always detect the species when it is present — which means occupancy rates may actually be higher than estimated. This, say the researchers, indicates a level of uncertainty in most previous conclusions about links between occupancy of stream-associated amphibians and forest practices.

Ensatina salamander is a common terrestrial salamander in the Pacific Northwest.

Research is showing that amphibians have different habitat requirements than fish.

Not all scientists agree that this uncertainty is a big problem; scientific studies always have a measure of uncertainty. Progress is being made on accurately estimating detection probabilities, says Marc Hayes of the Washington Department of Fish and Wildlife, another symposium presenter. An accumulating body of mark-and-recapture studies and other systematic surveying and re-surveying of sites is yielding more reliable population estimates. “We don’t know at this point how far off some of these estimates are,” he says, “but we are moving toward improvement.”

In the meantime, it’s possible to work around the problem and still do effective science, says Aimee McIntyre. “Even if you can’t say with confidence that the detection probability is 1 — and with amphibians you probably can’t — if the detection probability is relatively constant through time, across repeated visits or among experimental treatment types, it’s possible to collect valid indices of abundance, which can be used to determine trends through time.”

SUMMARY

A significant fraction of Northwest amphibian species depend on perennial and seasonal headwater streams, and many of the others are associated with forest riparian habitat. Forests are central to the Northwest’s ecology, economy and culture, which makes protection of forested wildlife habitat — including amphibian habitat — an important public issue. Historical timber-harvesting practices changed forest ecosystems significantly, altering habitat for riparian-dependent wildlife, including amphibians. The short- and long-term effects of contemporary forest practices, which are governed by protective requirements including retention of riparian buffers, are harder to document.

Olympic torrent salamander

Recent science about stream-associated amphibians is yielding insights into aspects of amphibian habitat, population dynamics and responses to habitat disruption, as well as refinements of research methodology. Particular themes include:

- the role of microsite characteristics,
- the importance of connectivity across headwaters,
- the efficacy of streamside buffers,
- the duration of impacts from harvesting, and
- the importance of improving methods of population sampling.

While it is too early to generalize to specific management prescriptions, this research shows that amphibians have habitat requirements different from those of fish and may, therefore, benefit from different approaches to habitat protection. From a regulatory standpoint, amphibians, by default, often fall under habitat-conservation measures now in place for fish. This research suggests that amphibian-specific protective measures may be called for in some parts of the landscape. For example, some findings suggest that additional protection for amphibians may be warranted in some areas, notably in and around non-fish-bearing headwater streams; whereas, on some lower reaches, amphibians may not need the extent of protections now in place for fish.

These findings are helping to frame a conversation about appropriate, specific habitat protections for amphibians in managed forests. Improving techniques for estimating presence and abundance of populations will improve the rigor of studies that can verify the efficacy of a variety of protection measures across the wide range of amphibian habitat conditions in Northwest forests. As findings become more conclusive in the next few years, it is reasonable to suppose that more-targeted, more site-specific protection measures could be devised that would protect amphibians at least as effectively as the current ones do, while still permitting a substantial level of forest management. Such measures could allow forest landowners to manage their harvesting operations more cost effectively and with greater confidence that their conservation efforts actually work.

The implications of the uncertainty posed by climate change, invasive species and disease are huge. As noted at the beginning, they are beyond the scope of this paper. But alone or together, they have the potential to transform the Northwest's forest landscape in unpredictable ways, possibly overwhelming the best measures of well-intentioned land managers. Any conversation about appropriate protection for amphibians should take place with awareness that these forces could change the whole playing field.

Washington experiment is biggest, most complex so far

A large-scale, replicated experiment on managed headwater forests in western Washington promises to help scientists better pinpoint the key factors in sustaining habitat for stream-associated amphibians in managed forests.

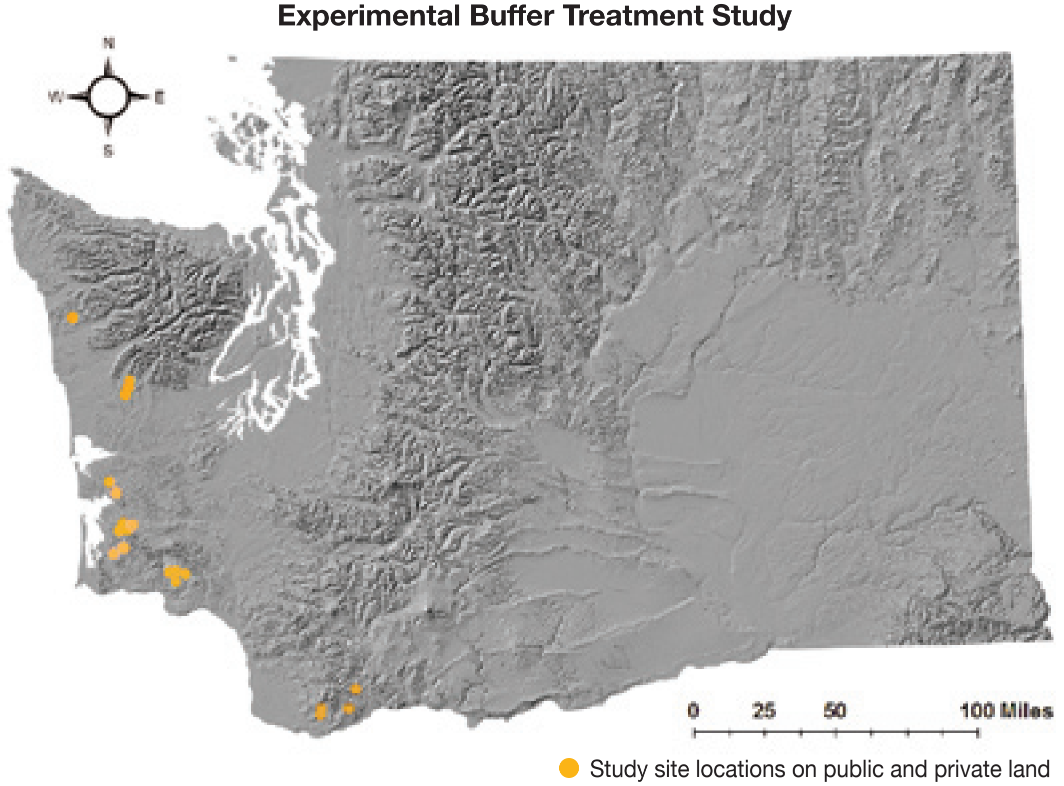
Using geographic information system maps, researchers from the Washington Department of Fish and Wildlife identified 36,000 candidate headwater stream basins on public and private lands. To qualify for the study, a site had to pass rigorous criteria; it had to be:

- a non-fish-bearing stream occupied by stream-associated amphibians (coastal tailed frogs — either Cope's or coastal giant salamanders — and one of the three torrent salamander species),
- under current active management and harvested in the past,
- one which met a specified harvest schedule, and
- big enough to accommodate an entire harvest unit.

The initial screening, which narrowed the number of qualified basins to 20, took two years and cost more than $250,000 by itself — "It was something of a hair-pulling operation for my study coordinator, Aimee McIntyre," the department's Marc Hayes says. The team ended up with 18 sites that fit the criteria. The sites were located on federal and state forestlands and private industry lands.

The treatments consist of clear-cut harvesting with one of three buffer configurations. The first configuration consists of the 50-foot buffers required by Washington law along both sides of non-fish-bearing streams. The buffers must cover at least 50 percent of the stream length, including certain special sites (i.e. certain categories of seeps).

Experimental Buffer Treatment Study



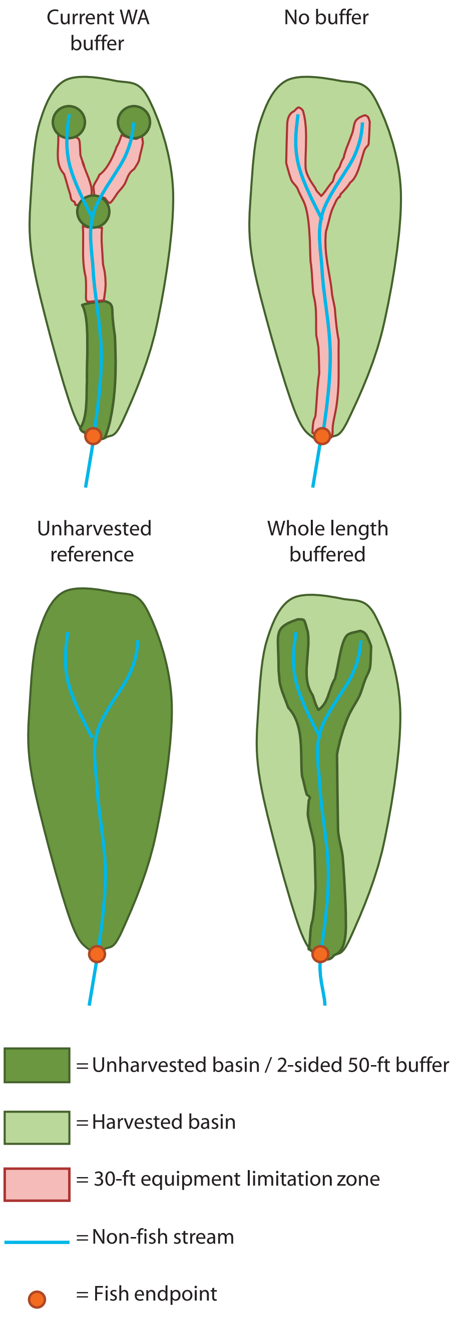
The second treatment is the same 50-foot buffers applied to the whole length of the non-fish-bearing stream. The third is harvesting without leaving any buffers, but with machinery excluded from within 30 feet of the stream (the streamside area can be logged but the yarding must be done from outside that machine-exclusion zone).

Each group of treatments also has an unharvested reference, or control, site. These are previously harvested sites withheld from this current harvest. Comparing study sites with control sites makes it possible to distinguish harvest-related changes from environmental changes that may affect all sites.

Researchers measured amphibian populations before harvesting and are repeating the measurements afterward (the measurements are still ongoing). They hope to monitor the populations for at least a decade. In addition, they assessed the genetic diversity of some of the species before the harvest and will assess it again seven or eight years later in the succeeding generation. They hope to find out whether genetic traits are being passed smoothly from one generation to the next. A genetic “bottleneck,” indicating that fewer individuals are contributing to the next generation, would be much stronger evidence of population decline than could be achieved by simple before-and-after population counts. The genetics study will also sample for genetic links between amphibians on the study sites and those in adjacent areas to get an idea of gene flow across the larger landscape.

Harvesting started in 2008, after the team had collected three years of pre-harvest data. The project has already encountered unexpected complications: the severe windstorm of December 2007 caused blowdowns on some of the study sites, which necessitated an additional year of sampling. Additionally, the 2009 economic crisis delayed harvest on two sites. Nevertheless, the researchers have made appropriate adjustments and plan to carry on through years 10 and 11, at least.

Buffer configurations within the study



Two long-term Oregon experiments yield information on contemporary management practices

Two long-term paired watershed studies promise to yield comprehensive information on how contemporary forest management affects amphibians, especially those associated with headwater streams. The studies are conducted under the umbrella of the Watersheds Research Cooperative, a broad-based partnership of forest sector companies, public agencies, nonprofits and other organizations based at the Oregon State University College of Forestry.

Paired watersheds are watersheds that are similar in their key characteristics. In the three studies, one of the watersheds is treated with some forest management activity and the other is left untreated for comparison. The study watersheds are in the Trask drainages in the Oregon Coast Range and in the Hinkle Creek basin of the Cascade foothills north of Roseburg (Watersheds Research Cooperative, 2008 and 2009). Scientists are taking comprehensive measurements of amphibian presence, abundance and habitat features, along with many other environmental conditions, before and after the harvest treatments.

All the study basins contain second-growth or third-growth actively managed forests. The Trask study will compare the effects of clearcutting and thinning with and without buffers on environmental conditions in non-fish-bearing headwater streams. The Trask study began in 2006 and will run through 2016.

The Hinkle Creek study, which began in 2001, will end in 2010. The harvests are complete and before-and-after data on amphibian survival, movement and density patterns have been gathered, according to Michael Adams, research ecologist with the U.S. Geological Survey, who leads the amphibian research. It is too early, Adams says, to draw any conclusions. The main amphibian species found at Hinkle Creek is the coastal giant salamander.

Giant salamander was the primary species found during research at Hinkle Creek.

The large-scale (13-basin) Trask study is expected to provide data on tailed frogs, which are considered sensitive.

Adams and his colleagues are conducting extensive mark-and-recapture studies in the Trask basin — capturing larvae and adults of tailed frogs and other amphibian species and marking each individual with a unique fluorescent code. After the harvest treatments scheduled for 2011-12 are completed, the team will go back in and survey for the marked individuals (as well as any others that might be there).

"One of the unique things we're trying to do with this study," Adams says, "is look at the movement of amphibians relative to timber harvest." The team is monitoring tailed frogs both within the harvest units and downstream to see whether the animals are moving in response to the harvest operation (Adams, personal communication).

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For further reading

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