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Science
FINDINGS

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

ARISE, AMPHIBIANS: STREAM BUFFERS AFFECT MORE THAN FISH

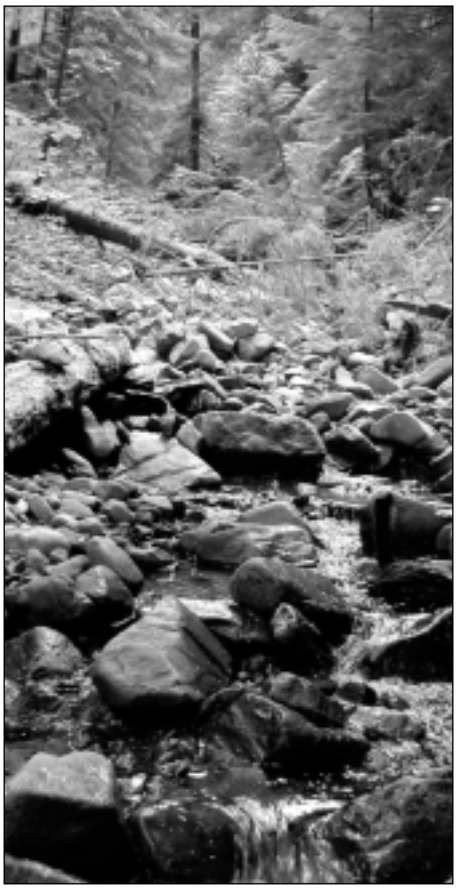
"How tortoise-like,
but not so slow,
These rational amphibii go!"

Andrew Marvell 1621-1678

When the Northwest Forest Plan was put in place on federal lands in 1994, one of its key foundations lay in streamside buffers, designed by the Forest Ecosystem Management Assessment Team (FEMAT) to support riparian habitat by providing functional stream and streamside ecosystems. Buffering of federal streams, from headwater and intermittent streams to large streams and rivers, combined with state-level conservation plans, and new management practices on private lands, affects a large portion of the land base. The quantity of buffered federal land alone ranges from 30 to 70 percent across the Pacific Northwest depending on the density of streams in a watershed.

"These buffers are meant to conserve habitat conditions not only for at-risk stocks of fish but also a diverse range of riparian-associated organisms including lichens, liverworts, fungi, vascular plants, invertebrates, and vertebrates," says Martin Raphael, a research wildlife biologist with the Pacific Northwest Research Station.

The size of the buffers, determined during the forest ecosystem management assessment process in 1993, was determined from a thorough review of existing literature, he says. But few field data were available comparing the efficacy of alternative buffer designs. Raphael believes that understanding relations between biodiversity and watershed function and condition may lead to opportunities to better balance commodity production and protection of streamside habitat.



Credit: L. Jones

Small steep streams make up the majority of the drainage network in Olympic Peninsula watersheds.

IN SUMMARY

Buffers along streams cover a tremendous proportion of the land base in the forested systems of the western Pacific Northwest. These buffers were designated primarily to conserve and restore habitat for salmon and trout, but conservation of habitat for a number of other organisms also has been implicit in their design.

Recent research evaluated the importance of buffers in providing habitat for other vertebrates, especially amphibians, whose decreasing numbers are raising concerns worldwide. Riparian buffers constrain management options along streams and encumber trees that might otherwise be harvested for commodity production. Thus understanding the importance of buffers for wildlife habitat is important in evaluating options for management.

Researchers examined small headwater streams on Washington's Olympic Peninsula with buffers that were put in place prior to implementation of the Northwest Forest Plan. These riparian buffers were, for the most part, narrower than those prescribed by current guidelines. Preliminary results suggest closer attention needs to be paid to nonfish species in these locations, particularly the sensitive amphibians.

Specifically, how does active management (that is, vegetation management within riparian zones) affect the stream and riparian species that are theoretically protected by buffers?

Many recent studies have shown that watersheds containing mostly young, managed forests have reduced diversity of aquatic and terrestrial vertebrate populations. As a result, the emerging practices of ecosystem management have embraced the idea of restoring riparian areas to conditions more like those created by natural processes explains Peter Bisson, a research fish biologist with the PNW Research Station .

"Virtually all aquatic species and many terrestrial plant and animal species closely associated with riparian zones are sensitive to management-induced changes in riparian condition," he says. "The way these species respond to anthropogenic disturbance is usually complex and strongly influenced by ecological processes at a particular site. Thus it is difficult to predict how a particular ecosystem will change following a management activity."

KEY FINDINGS

- Bird, resident fish, and mammal community composition and structure are generally comparable between buffered and intact streamside forest, although responses to harvest are complex.
- Amphibian populations decline sharply after timber harvest, and with narrow streamside buffers. Furthermore, populations are slow to recover in second-growth forest, and different species do so at different rates.
- Amphibian recovery depends on recolonization of riparian areas as surrounding second-growth forests mature. Recolonization depends on retaining patches of uncut old forests as refugia or sources of dispersing amphibian populations.

GETTING INTO THE ZONE

Bisson notes that despite the acknowledged importance of riparian zones to fish and wildlife, relatively few studies have examined the response of riparian systems to management alternatives for commodity production, riparian protection, or restoration. He and Raphael recently completed phase 1 of the riparian ecosystem management study (REMS) to explore these effects.

A number of key riparian buffer questions still need addressing. What buffer widths and configurations are needed to protect fish and wildlife habitat along different stream types? What proportion of riparian zones should remain in different forest growth and development stages over broad landscapes? Can riparian vegetation be deliberately managed for the benefit of aquatic or terrestrial wildlife?

It was the last question that informed the design of REMS. The study examined the effect of different streamside buffers on the major aquatic vertebrates, including fishes, amphibians, birds, and small mammals. Species included trout, sculpins, tailed frogs, salamanders, 20 species of birds, and five common species of shrews and mice.

Sixty-two streams and associated riparian zones were examined on Washington's Olympic Peninsula from 1996 to 1999. Most study sites were located in small watersheds, with about one third too small or steep to support fishes.

"These small streams comprise a huge network in an area of high drainage, like the Olympic Peninsula," says Raphael. "Probably 75 to 80 percent of the landscape is close to, or strongly associated with, the small-stream network."

"Our study is one of the first to emphasize very small headwater streams. Most other studies have had a fish focus, and REMS has added many other species to the mix," Bisson adds. "This is not least because of increasing interest in aquatic organisms other than fishes, particularly the declining numbers of amphibians, and the need to better understand riparian buffers as crucial landscape components for small mammals and birds."

The researchers used a retrospective approach, involving comparisons of many sites, representing differing times since logging and different buffer characteristics. The retrospective approach ("substituting space for time") provides a great deal of information fairly rapidly, but the researchers acknowledge that it doesn't offer true control over buffer size in relation to size of streams, topographic relief, and other landscape attributes. "We have to take what the landscape offers us and try to unravel the confounding effects of such things as topography and gradient," Raphael says.

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A LANDSCAPE REVEALED

Unexpectedly, when the researchers set out to locate study sites, they discovered that almost no sites on the peninsula offered the conditions proposed by the Northwest Forest Plan. So much of the landscape either had already been managed before that plan was in place or was kept out of the matrix lands available for management by supporting threatened or endangered species, that little was left in the buffered but managed category on federal lands.

"The result was that our study ended up looking at buffers that are more similar in nature to State and Private managed lands, from the times when smaller buffers were required," says Bisson. "Within this investigation, we found no streams with large Northwest Forest Plan buffers—either one or two tree heights wide, so we were unable to evaluate that particular buffer treatment."

LAND MANAGEMENT IMPLICATIONS

- Fish population densities are highly variable from site to site, probably influenced more by presence or absence of recent large disturbance events than adjacent forest barriers. In-stream disturbances are probably more influential to fish than buffer width.
- Birds and mammals are relatively mobile and probably have a reasonable recolonization ability.
- Amphibians are a good indicator of change in the environment. After timber harvest, numbers and diversity drop sharply; some species had not reestablished populations by the time next harvest was to occur. Where existing stream buffers of old forest were narrow, they did not ameliorate the effects of logging the adjacent stand.
- Conservation of riparian forest helps maintain distribution of stream-associated amphibians; sources of refugia are essential. Evaluation of streamside forest at the scale of entire watersheds will help determine prospects for long-term persistence and local viability of amphibian population.

Instead, virtually all study sites were in unmanaged watersheds or areas previously logged according to older buffer strip guidelines that permitted timber harvesting to within 10 to 30 meters of the channel. Most sites, even those on the Olympic National Forest, had been managed with a heavy emphasis on wood production. Nonetheless, the Olympic Peninsula uniquely offers a concentric series of landscape types around the largely wilderness core of Olympic National Park that are a microcosm of the western part of the Pacific Northwest, Bisson notes.

Six site conditions were represented: old sites (unmanaged with intact forest on both sides of the stream); buffered old sites (old forest with adjacent clearcuts leaving buffers of 10 to 30 meters); mature sites (second-growth stands 35 to 100 years old with no adjacent harvest); thinned mature sites (intact second growth with commercial thinning); buffered mature sites (second growth with adjacent clearcuts leaving 10 to 30 meters of second-growth forest); young sites (cutover sites with no intact buffers, generally up to 35 years old).

Site types were not equally distributed across the study area because of differing ownerships and management practice histories.

SITE VERSUS LANDSCAPE: WHICH DRIVER?

The REMS project was designed to evaluate vertebrate responses to riparian management at the site level—typically a 300-meter reach of stream and associated riparian area.

"But we could not ignore the possibility that fishes and amphibians may have been influenced by broad-scale characteristics of the watersheds they inhabited, irrespective of the condition of the immediately adjacent riparian zone," Bisson says.

Initial analysis of the relationship between various vertebrates and site-level features such as channel type, number of pools and riffles, substrate, and gradient, left many unanswered questions about what environmental factors were most influential, he explains. So the researchers expanded the assessment to take in landscape-scale factors such as forest age, drainage characteristics, elevation, road density, and disturbance history.

"We always thought the land-scape level factors would have an influence on the riparian zone," Raphael says. "The challenge comes in teasing those out from the site-level effects."

Raphael and Bisson looked for statistical correlations among their array of variables, by using an approach that recognized the complexity of relationships between vertebrate population densities and the many variables in their data set. Because of the expense of examining these variables via field data, they designed a separate investigation of the data after the main study to determine cost effectiveness of various indicators as units of analysis.

"The thought was that some of this would be very useful for monitoring purposes, to find which kinds of site- or landscape-level factors might be inexpensive to track and yet provide a good 'signal' for effects in the riparian zone," Raphael explains. "We sought factors that have a high signal-to-noise ratio to keep research or monitoring costs down." This involved deriving the "information value" of various factors—looking at the relative cost of obtaining them and seeing which were most explanatory in terms of organism abundance. It provided a kind of menu of things you'd like to know, Bisson explains, and how much they can tell you, relative to the cost of finding them out.

DISAPPEARING FROGS AND SALAMANDERS

"Amphibians proved to be the most responsive to riparian forest condition and the amount of late-seral forest in their watersheds," Raphael says. "While some seemed to be adaptive generalists, others were more sensitive to forest management in or near the stream zone. Our study suggested that stream-dwelling amphibians were negatively affected by management activity near small streams; their densities dropped sharply after timber harvest."

Across the categories of sites, it appeared that riparian areas composed of young-early successional forests did not support amphibian populations at the densities observed in late-seral sites, he says. Generally, they were most numerous and diverse in old forests. This was not caused by changes in stream temperature: most streams, regardless of previous forest management history, maintained temperatures within the critical thermal limits of even sensitive species.

"Overall, the key finding around amphibians is in regard to their recovery," Raphael says. "While not all species respond the same way, there is typically a rapid decrease in population after management activity in the riparian zone, and recovery for some species can be quite slow. In some sites, the numbers are still low as much as 60 years after timber harvest." In other words, around the time harvest might be considered again.

It is not clear whether the drop in numbers results from mortality or downstream dispersal, but recovery appears to depend on several main factors, according to Raphael: retention of patches of uncut older forest to serve as refugia or sources of dispersal, and recolonization of riparian areas as surrounding second-growth forests mature.

"Potential for large-scale reduction in amphibian numbers is high, and indeed the focus on amphibian population decline worldwide is increasing. It seems clear that amphibian numbers should at least be considered as part of the buffer zone assessment and recommendation process," he says.

Other vertebrate species showed less alarming trends, with variable responses reflecting the complexity both of the research question and the landscapes in which sites are nested.

COMPLEX REACTIONS FROM BIRDS, FISH, AND SMALL MAMMALS

Fishes demonstrated the differences in response between site- and landscape-level factors. The study showed little association between species abundance and riparian forest age or the percentage of older forest in the watershed, according to Bisson. However, they tended to be strongly influenced by the condition of instream habitat.

"Although the riparian forest probably influenced in-stream habitat, our results suggested that the number and size of pools and other habitat parameters important to fishes was likely controlled by a number of other factors, including recruitment of logs and large boulders to the channels by bank erosion, landslides, debris flows, and other disturbance mechanisms," Bisson says.

Other parameters affecting the local abundance of fishes in these headwater streams included elevation of the watershed, gradient of the channel, and the amount of primary production—aquatic plant production controlled by light and nutrients. Headwater streams on the Olympic Peninsula are typically disturbance prone, Bisson explains, as this was reflected by the variability in fish populations from site to site.

Credit: P. Bisson

Tailed frogs inhabit headwater streams and are sensitive to changes in riparian forests.

Credit: L. Jones

Cope's giant salamander is an important predator in headwater streams.

In general, fish abundance did not differ significantly by buffer type, but differed among other site attributes except stream width. Bisson notes that abundance of fishes was affected significantly by elevation, and parent rock appeared to be more important for fishes than for other vertebrates.

"Thus, at the site level, we accepted the hypothesis that the characteristics of the riparian forest had no influence on fish abundance in these stream," Bisson says.

Responses of birds to forest conditions along streams were also highly variable. Of the 20 species of birds whose abundances differed significantly among site conditions, a majority (13 species) reached their highest abundances in mature sites with buffers. In these sites, a diversity of habitats included large trees, brushy conditions, open ground, a forest edge, and a riparian to upland interface, Raphael explains. Abundance of birds was generally greater at lower elevation sites with flatter gradients and at higher elevations. An exception was the American dipper, which was more abundant in wider streams, and most abundant in cutover, young sites.

WRITER'S PROFILE

Sally Duncan is a science communications analyst and writer specializing in natural resource issues. She is currently a Ph.D. candidate in Environmental Sciences at Oregon State University in Corvallis.

Among small mammals, significant differences among site conditions appeared only for the Pacific jumping mouse among the five common species surveyed. Slight variations according to elevation and gradient were apparent, but correlations were weak. The researchers emphasize that their results should not be extended beyond the limited number of small mammal species they were able to capture.

"Our results indicate that fishes, birds, and mammals—at least the more common species that were abundant enough to make valid comparisons—persisted in sites after logging whether or not buffers were present," Raphael says.

CLEAR IMPLICATIONS FOR MANAGEMENT?

Predictable relationships between species abundance and management activities will require calibration with local data, Raphael points out, because local populations can be confined to small areas (resident headwater trout, amphibians with restricted distribution). Relations between management and species bounded on a very large scale (anadromous salmon, Neotropical migratory birds) are more difficult to establish.

Most headwater organisms are controlled by multiple biotic and abiotic factors, and changing a single variable, particularly at the landscape level, will not reliably result in a predictable response in vertebrate populations. Relying on an alternative approach of simulation modeling or landscape analysis often involves many untested and often incorrect assumptions, Raphael notes, but should continue alongside species investigations to keep building knowledge.

Despite REMS providing such variable results, and its being based on relatively narrower buffers than the Northwest Forest Plan imposed, there are still some indications for management flexibility, the researchers believe.

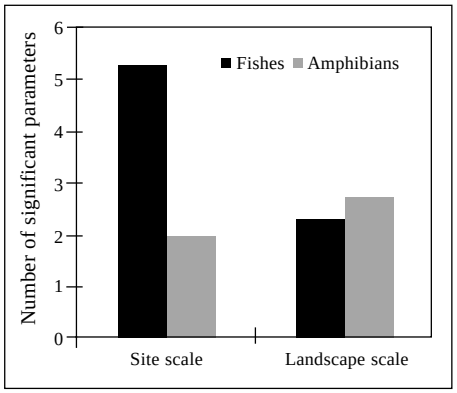
"Variable-width buffers, as opposed to fixed width, may be an option, provided the planning begins with conservative buffers around small streams. Then you can practice some management within riparian zones depending on local conditions," Bisson suggests. "I think some managers have come to regard the FEMAT-established buffers as more hard and fast than they were intended to be. With careful analysis, there are probably areas where you could formulate management prescriptions that depart from the default FEMAT recommendations."

Bisson recalls that during the REMS study, it became clear in many ways just how little we know about what lives in these small headwater streams. At the beginning of inventory for phase 2 (experimental) of the study, a number of new species of millipede, and possibly a previously unknown genus, have been discovered by a collaborating researcher.

"The most useful outcome of our study may in fact be to bring more scientific attention to small, headwater, non-fish-bearing streams and their riparian areas," he says.

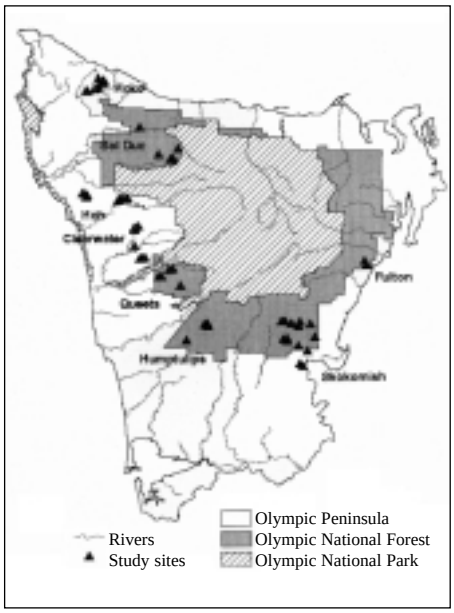
"I don't see no p'ints about that frog that's any better'n any other frog."

Mark Twain,
The Celebrated Jumping Frog, 1865



Credit: USDA Forest Service

Comparison of the average number of site scale and landscape scale variables significantly influencing fish and amphibian species in headwater streams on the Olympic Peninsula.



Credit: USDA Forest Service

Location of study sites on the Olympic Peninsula, Washington. Names of the major river basins (study sites) are indicated.

FOR FURTHER READING

Bisson, P.A. [and others]. 2002. *Influence of site and landscape features on vertebrate assemblages in small streams.* In: Johnson, A; Haynes, R. eds. Proceedings of the Wood Compatibility Initiative workshop. Gen. Tech. Rep. PNW-GTR-563. Portland, OR: U.S.Department of Agriculture, Forest Service. Pacific Northwest Research Station.

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