

Headwater streams and red alder

Alder colonizes both headwater and higher order river systems and provides nutrient subsidies throughout channel networks. The importance of red alder to the nutrient cycling of terrestrial and aquatic ecosystems suggests the designation of red alder as a keystone species within the Pacific Northwest. Red alder complements the structural stability of coniferous forests, providing nutrient subsidies that maintain and stimulate diverse and productive aquatic ecosystems.

A study conducted in western Washington showed that 2.5-15% watershed coverage of alder increased dissolved nitrate concentrations in streams to as high as $0.3 \text{ mg} \cdot \text{L}^{-1}$. Stream water nitrate concentrations from the Oregon coast range have shown similar values, with differences detected in stream water nitrate concentrations attributable to watershed coverage as low as 7% (Compton et al. 2003). Streams with high nitrate concentrations had significantly higher algae and invertebrate biomass production than sites with low stream water nitrate (i.e., coniferous streams) (Volk 2004).

Management

Aquatic ecosystems may be inadvertently affected by terrestrial management activities. In western Washington, forest harvesting is a common activity that alters the composition of watershed vegetation. Non-fish bearing, low-order (headwater) streams are rarely protected via riparian buffers, and aquatic community structure can be severely altered by harvesting events. Large-scale experimental manipulations have proved that these physical alterations can affect in-stream productivity, such as periphyton production (Kiffney et al. 2003). Similarly, a forest harvest in Hubbard Brook during the 1960s showed stream water concentrations of nitrate can be over forty-fold higher than in undisturbed conditions (Likens et al. 1970). Harvesting of trees on the banks of salmonid bearing, headwater streams can increase bank instability, sediment deposition, light availability, and surface water runoff (Kiffney et al. 2003). Alder colonization in these disturbed, western Washington landscapes is likely, further altering the nutrient regimes of streams in forest harvested areas.

Management of coniferous and alder-influenced landscapes should consider implications for both terrestrial and aquatic environments. Alder thinning and replanting studies could potentially use as low as $0.2 \text{ mg} \cdot \text{L}^{-1}$ (fall season) as a guideline for 'biologically meaningful' concentrations of nitrate in small Pacific Northwest streams. However, it is important to note that other factors, such as light availability and discharge, may be more limiting to stream productivity than nutrient availability.

Nutrients

Red alder provides a significant source of macronutrients to aquatic ecosystems. Comparison of streams dominated by red alder and old-growth conifer riparian forests suggests that selective macro- and micronutrient differences in water chemistry, suspended particulate matter, and periphyton resources occur in these streams. Nutrient and organic matter resources transported from red alder-dominated riparian areas into freshwater ecosystems may temporarily replace those lost due to salmon declines and supplement those nutrients derived from fish carcasses in areas with healthy populations. Moreover, maintaining alder forests may be critical to the recovery efforts of depressed salmon populations in the Pacific Northwest. Alder is an integral component of the riparian landscape, as it provides essential subsidies of limiting elements to stream and forest food webs while salmonid populations recover.

Higher concentrations of both macro- and micro- nutrients were found in leaf litter, seston, and periphyton from alder-dominated streams than in streams bordered by coniferous vegetation. Close correlations between periphyton, in-stream invertebrates, and trout populations suggested that these small, headwater streams rely heavily on autochthonous energy production. Not only is periphyton an abundant and readily used resource in high light streams, but it provides a more accessible source of N and P than ter-

restrial vegetation. Carbon isotope studies in northern California have shown autotrophic processes in small streams to be critical controllers of stream metabolism (Finlay 2003). Stable isotope studies in the Cedar River, Washington, have also shown aquatic food webs to be more closely related to autochthonous than allochthonous carbon sources.

Biota

Comparisons of red alder and conifer dominated streams suggest that water chemistry, suspended particulates, periphyton, and invertebrate biomass were influenced by the abundance of red alder within watersheds. In alder-influenced streams, algae and invertebrate communities had increased production of nutrient-rich biomass compared to coniferous streams. Nutrient limitation studies and periphyton fatty acid profiles suggested that algae communities might be unique to streams and related to instream nutrient levels. Invertebrate communities in alder streams were more diverse and had higher emergence and drift, suggesting that biomass cycling and transport between habitats may be faster in alder than coniferous streams. Alder litter, alder detritus, periphyton, and trout (P only) had higher N and P compared to conifer streams. Organic matter, periphyton, invertebrates, and trout were also enriched with essential fatty acids when influenced by alder or salmon nutrient subsidies.

References

- Compton J.E., Robbins Church M., Larned S.T., and Hogsett W.E. 2003. Nitrogen export from forested watersheds in the Oregon Coast Range: the role of N₂-fixing red alder. *Ecosystems* 6: 773-785.
- Finlay J.C. 2003. Controls of streamwater dissolved inorganic carbon dynamics in a forested watershed. *Biogeochemistry* 62:231-252.
- Ghosh M. and Gaur J.P. 1994. Algal periphyton of an unshaded stream in relation to in situ nutrient enrichment and current velocity. *Aquatic Botany* 47:185-189.
- Kiffney, P.M., Richardson J.S. and Bull J.P. 2003. Responses of periphyton and insects to experimental manipulation of riparian buffer width along forest streams. *Journal of Applied Ecology* 40:1060-1076.
- Volk, C.J. 2004. Nutrient and biological responses to red alder (*Alnus rubra*) presence along headwater streams: Olympic Peninsula, Washington. PhD. dissertation, University of Washington. Available online at: <http://depts.washington.edu/cwvs/Theses/volk.pdf>

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