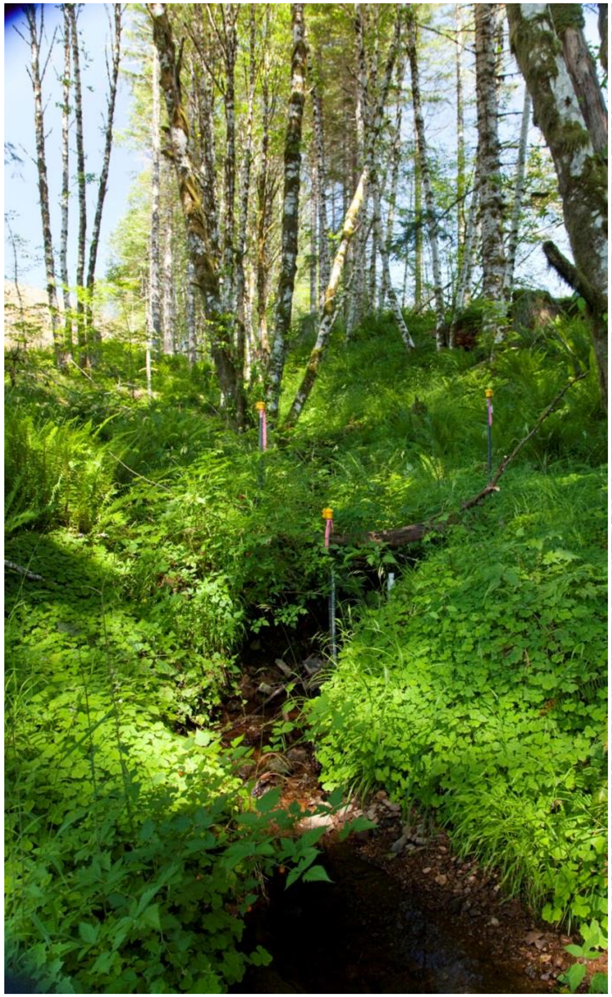
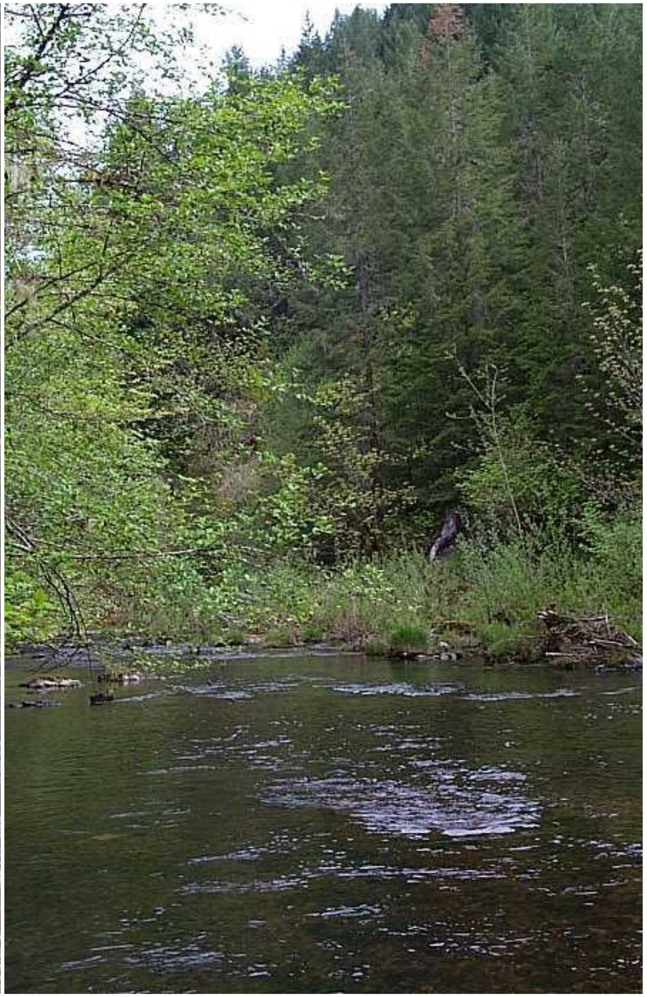
Riparian Area Functions





Maryanne Reiter, Hydrologist, Weyerhaeuser Company

WFCA Fish Habitat Workshop Sept 8, 2016 Heathman Lodge, Vancouver, WA.

This Talk

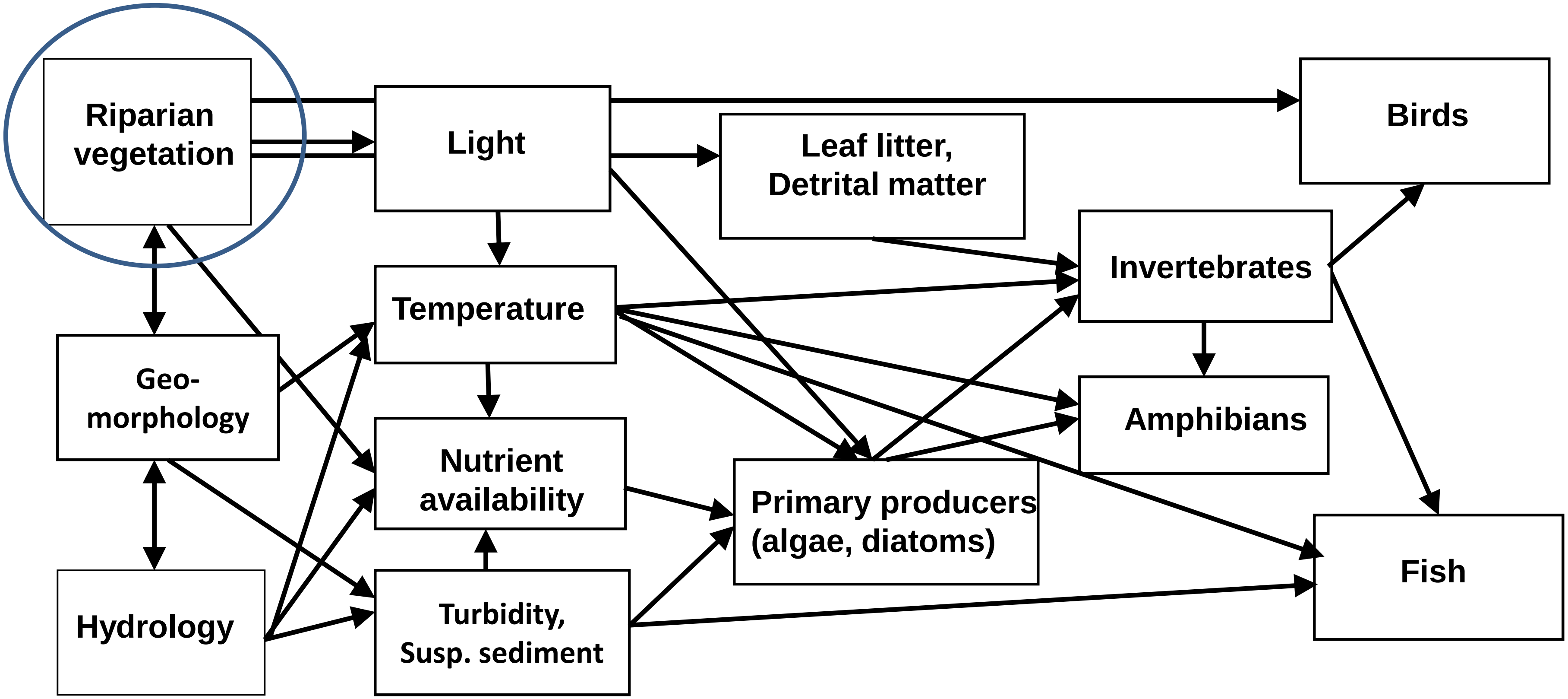
- Overview of riparian functions that are the focus of this talk
- How much have we learned about them through time?
- Functions dependent on scale (lateral and longitudinal) and landscape setting
- What are the future concerns for riparian areas?

What Are Some Riparian Functions?

- Shade (light, stream temperature, microclimate)
- Organic material input (large wood, litterfall)
- Sediment and chemical filtering
- Nutrient cycling
- Bank stability

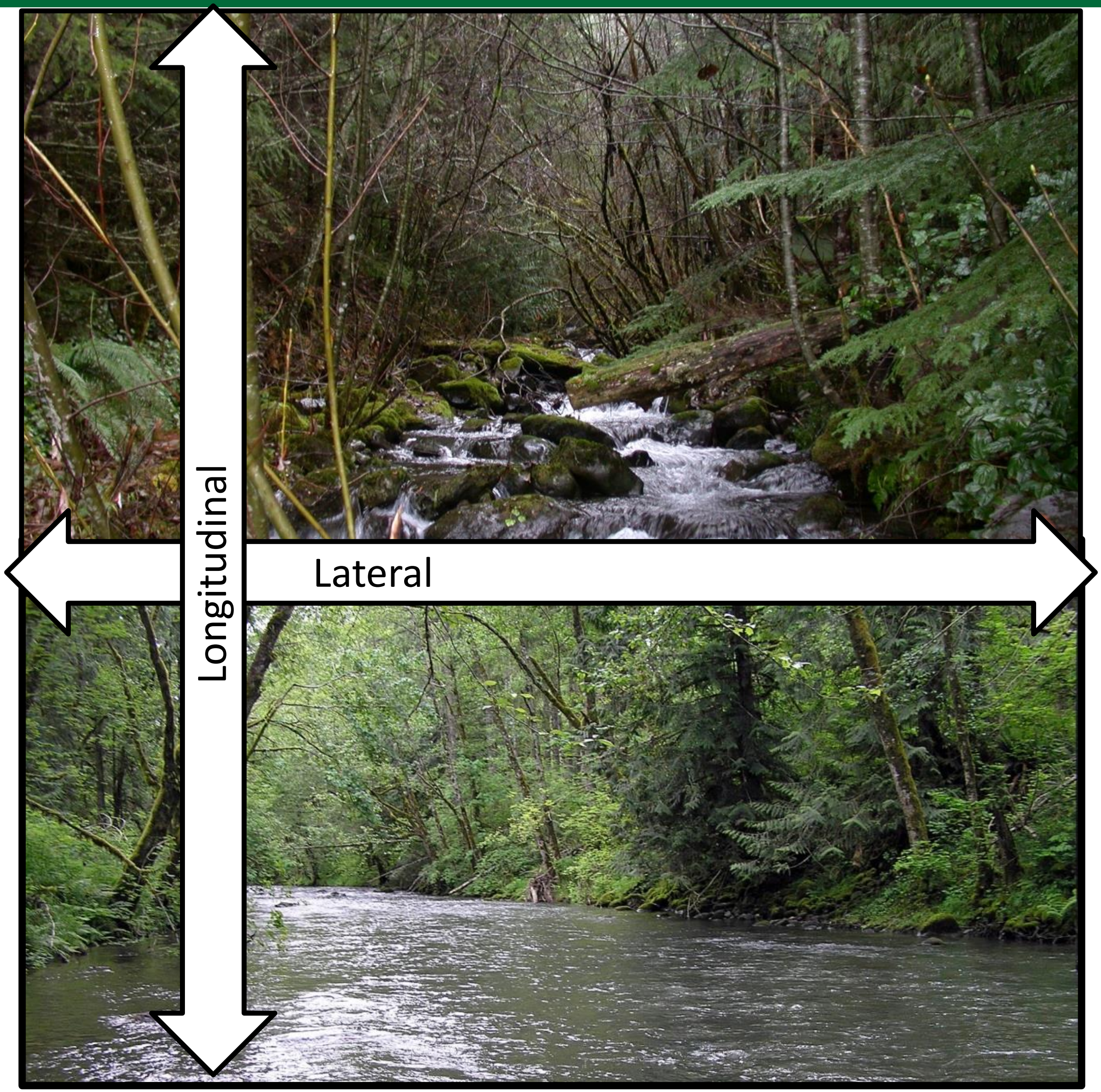
These functions vary depending on site and landscape characteristics.

But These Functions Do Not Occur in Isolation

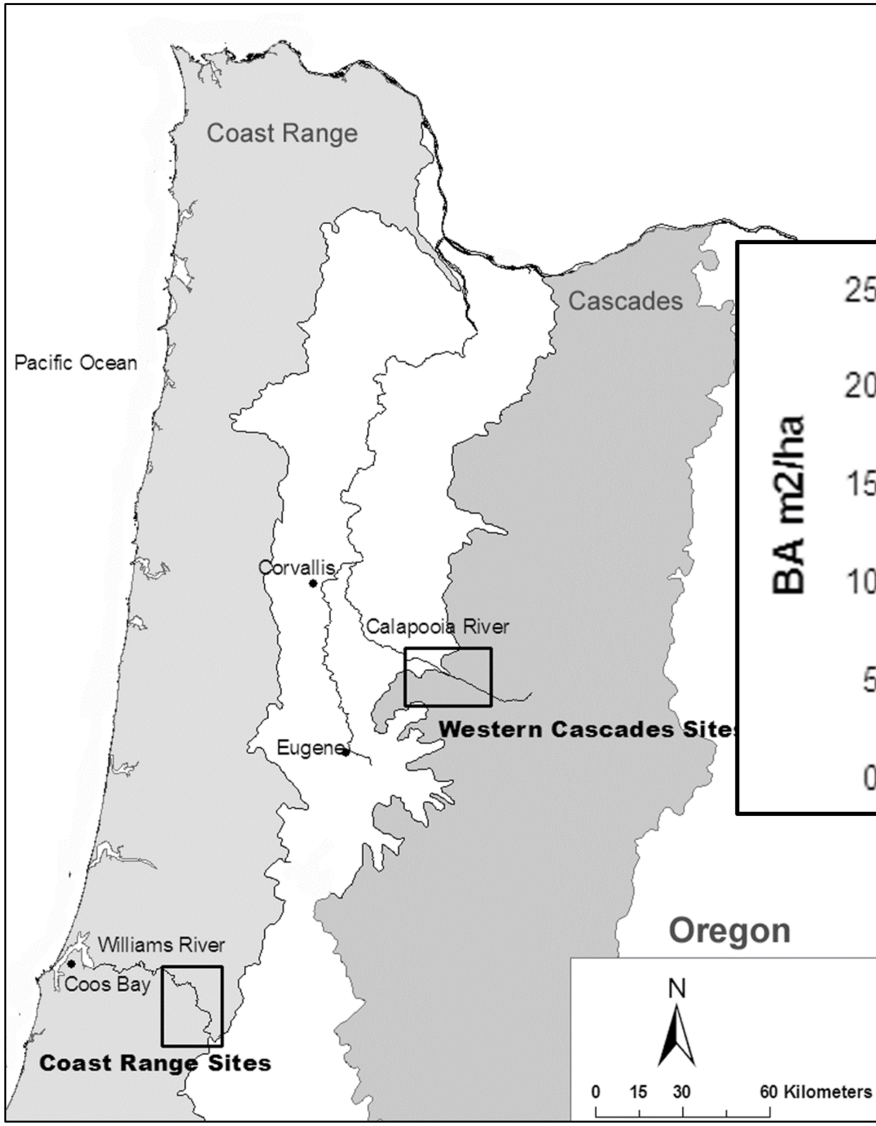


If the concern is aquatic habitat, then need to consider interaction of functions as well as upslope processes.

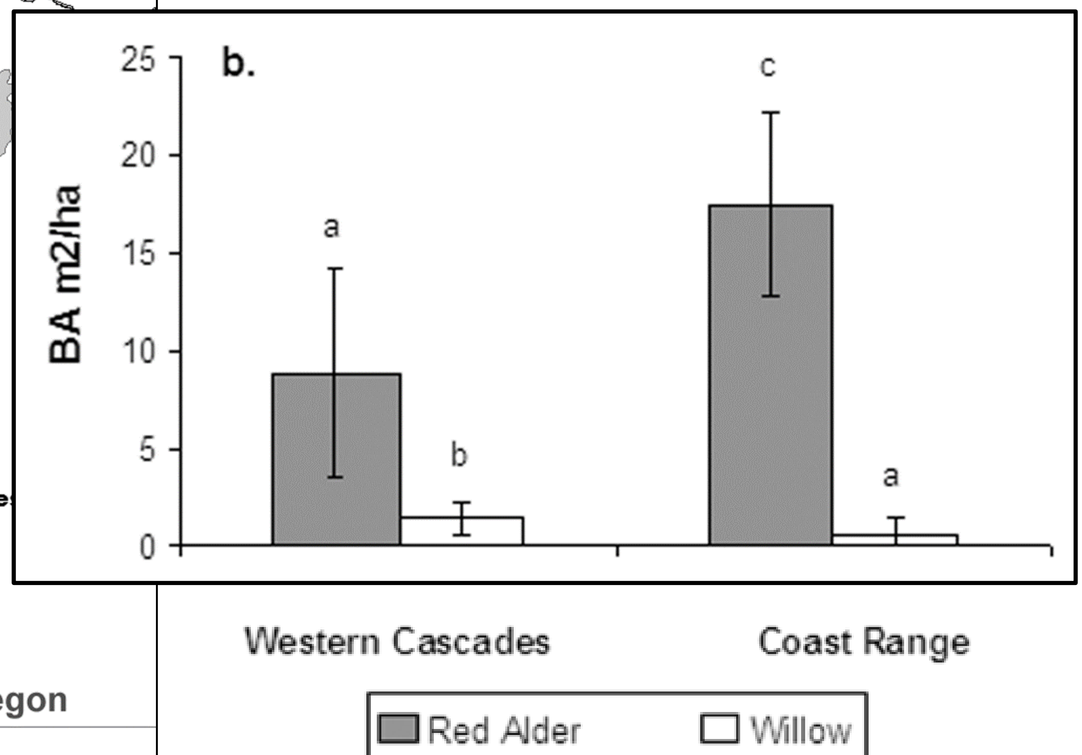
Riparian Functions Are Scale Dependent



Functions Are Location Dependent



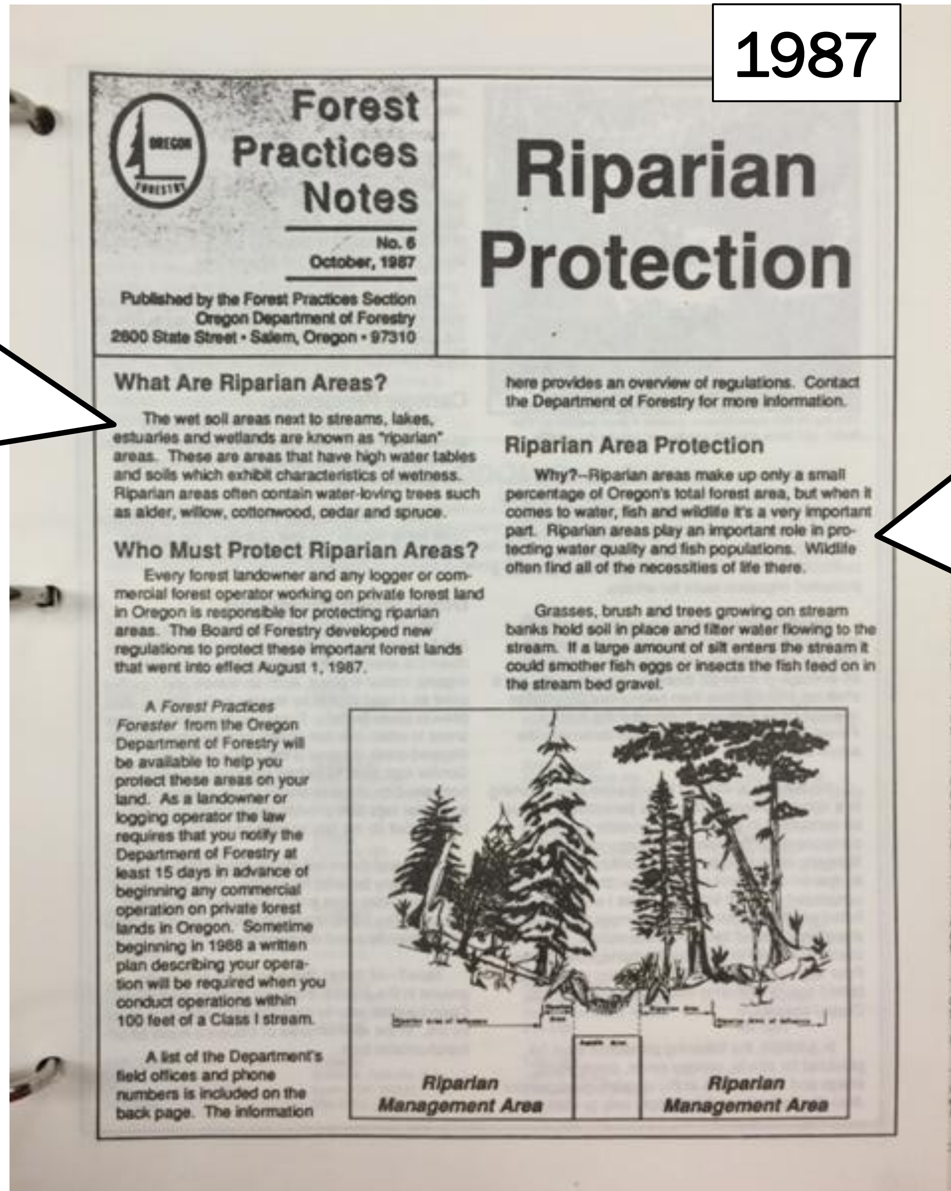
Red Alder recovery following debris flows



D’Souza et al., 2011.

Riparian Areas Have Been a Concern for Years

“What are Riparian areas? The wet soil areas next to streams..”



Forest Practices Notes

No. 6
October, 1987

Published by the Forest Practices Section
Oregon Department of Forestry
2600 State Street • Salem, Oregon • 97310

Riparian Protection

What Are Riparian Areas?

The wet soil areas next to streams, lakes, estuaries and wetlands are known as "riparian" areas. These are areas that have high water tables and soils which exhibit characteristics of wetness. Riparian areas often contain water-loving trees such as alder, willow, cottonwood, cedar and spruce.

Who Must Protect Riparian Areas?

Every forest landowner and any logger or commercial forest operator working on private forest land in Oregon is responsible for protecting riparian areas. The Board of Forestry developed new regulations to protect these important forest lands that went into effect August 1, 1987.

A *Forest Practices Forester* from the Oregon Department of Forestry will be available to help you protect these areas on your land. As a landowner or logging operator the law requires that you notify the Department of Forestry at least 15 days in advance of beginning any commercial operation on private forest lands in Oregon. Sometime beginning in 1988 a written plan describing your operation will be required when you conduct operations within 100 feet of a Class I stream.

A list of the Department's field offices and phone numbers is included on the back page. The information here provides an overview of regulations. Contact the Department of Forestry for more information.

Riparian Area Protection

Why?--Riparian areas make up only a small percentage of Oregon's total forest area, but when it comes to water, fish and wildlife it's a very important part. Riparian areas play an important role in protecting water quality and fish populations. Wildlife often find all of the necessities of life there.

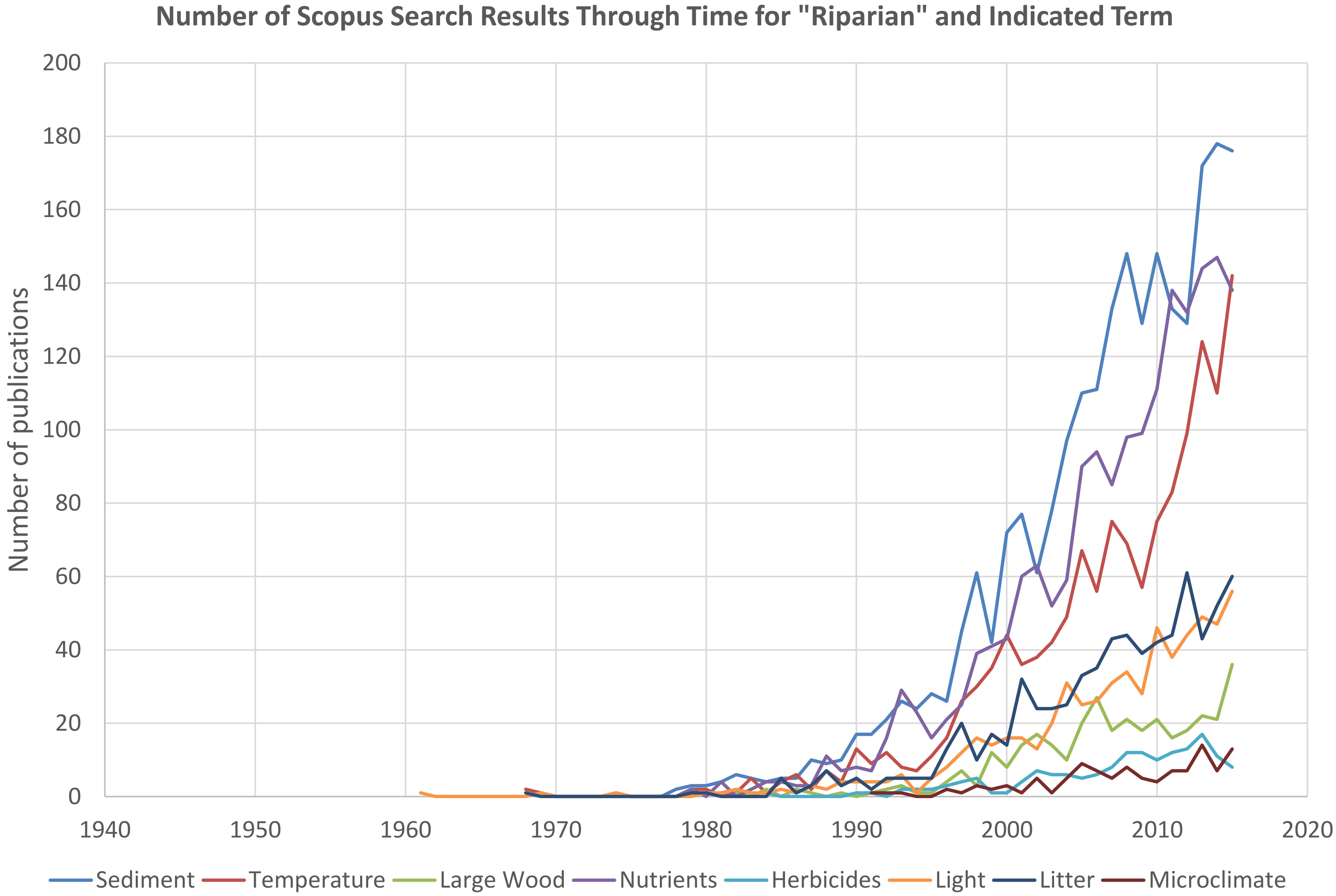
Grasses, brush and trees growing on stream banks hold soil in place and filter water flowing to the stream. If a large amount of silt enters the stream it could smother fish eggs or insects the fish feed on in the stream bed gravel.

Riparian Management Area

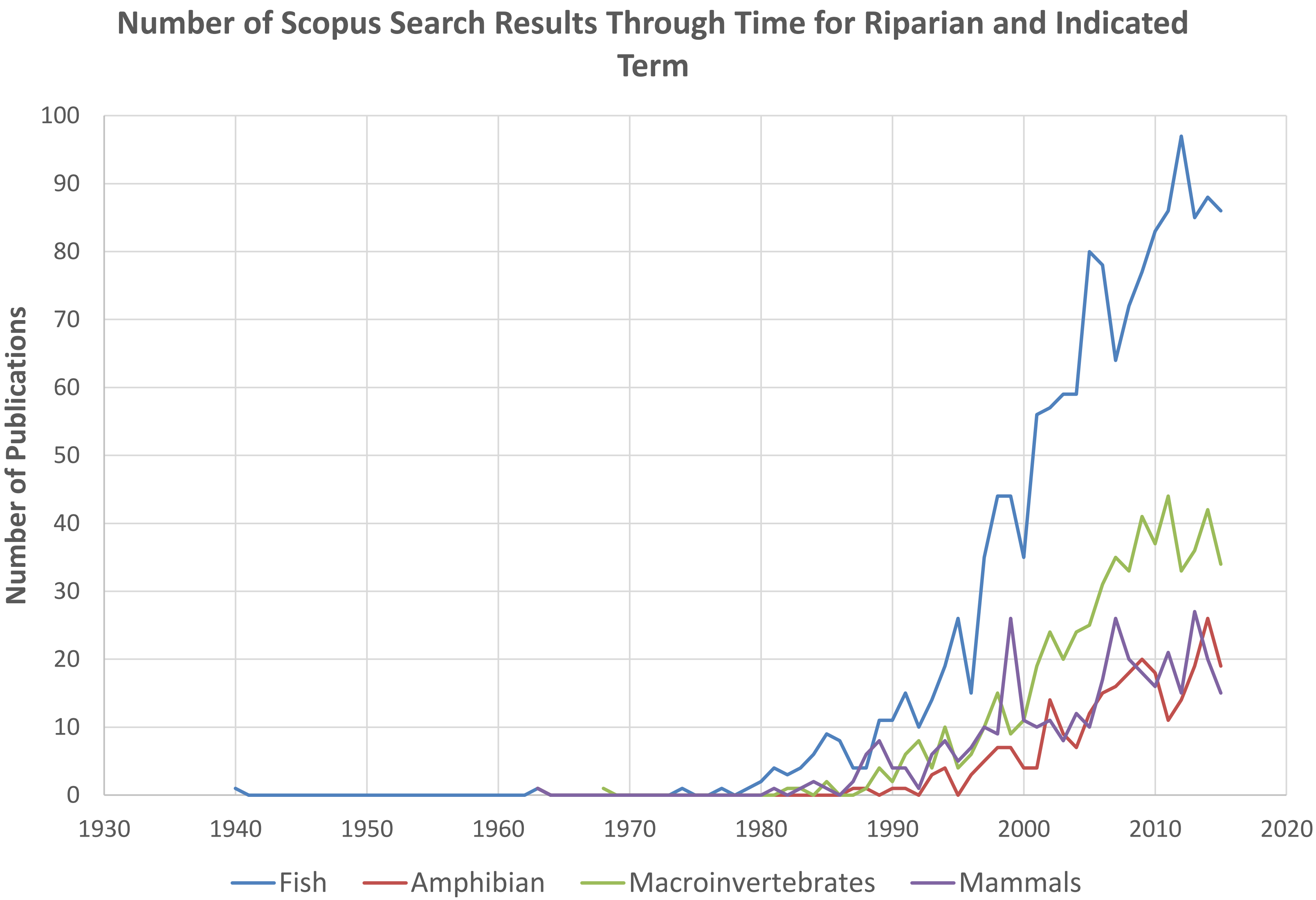
Riparian Management Area

“Riparian areas play an important role in protecting water quality and fish populations. Wildlife often find all the necessities of life there.

This Concern Has Led to Increased Research

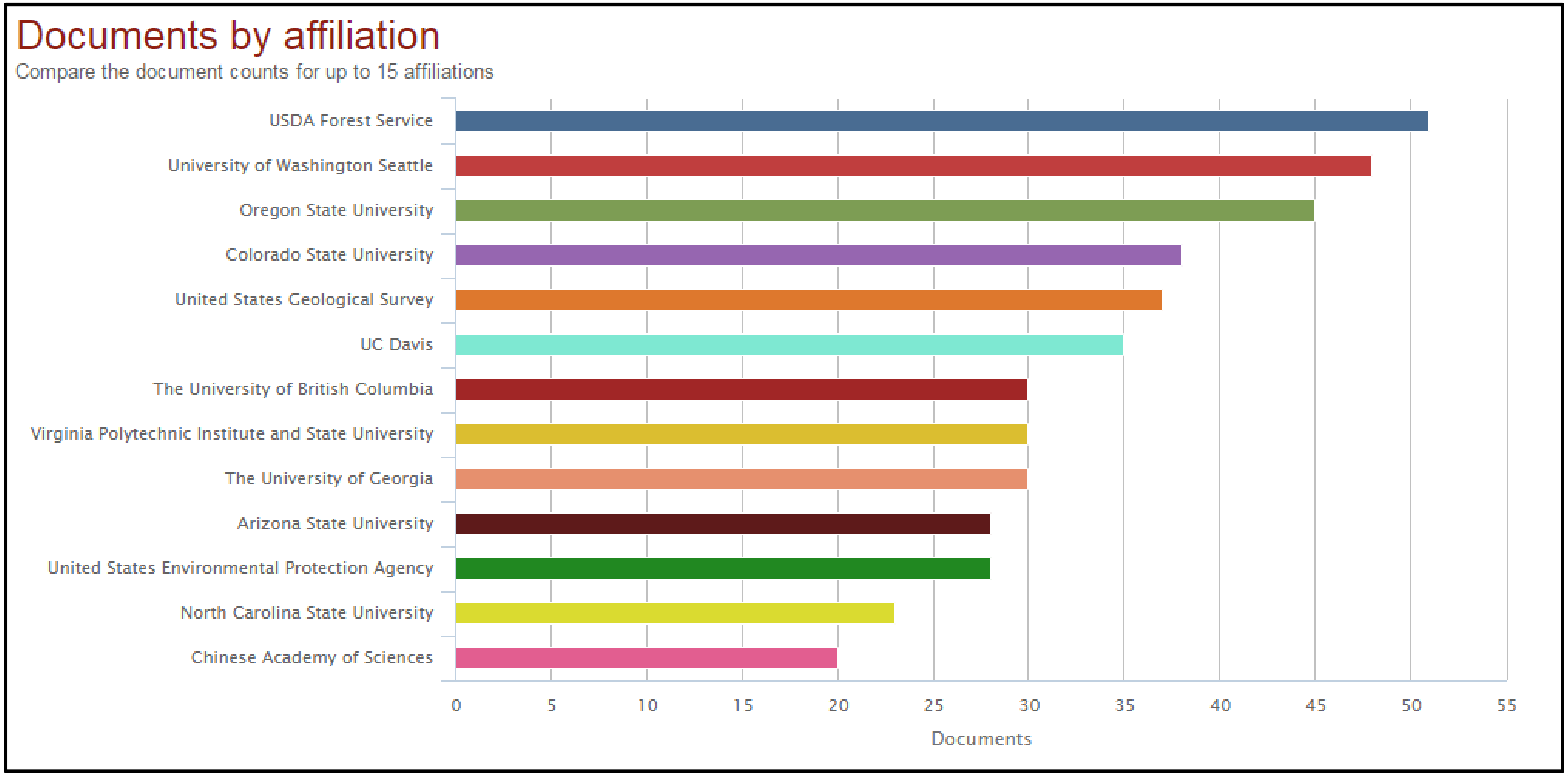


Biological-Riparian Interaction Publications



Who is Publishing on Riparian Function?

Scopus results for search terms “riparian” and “function”:
Who is doing the research and why is that important?

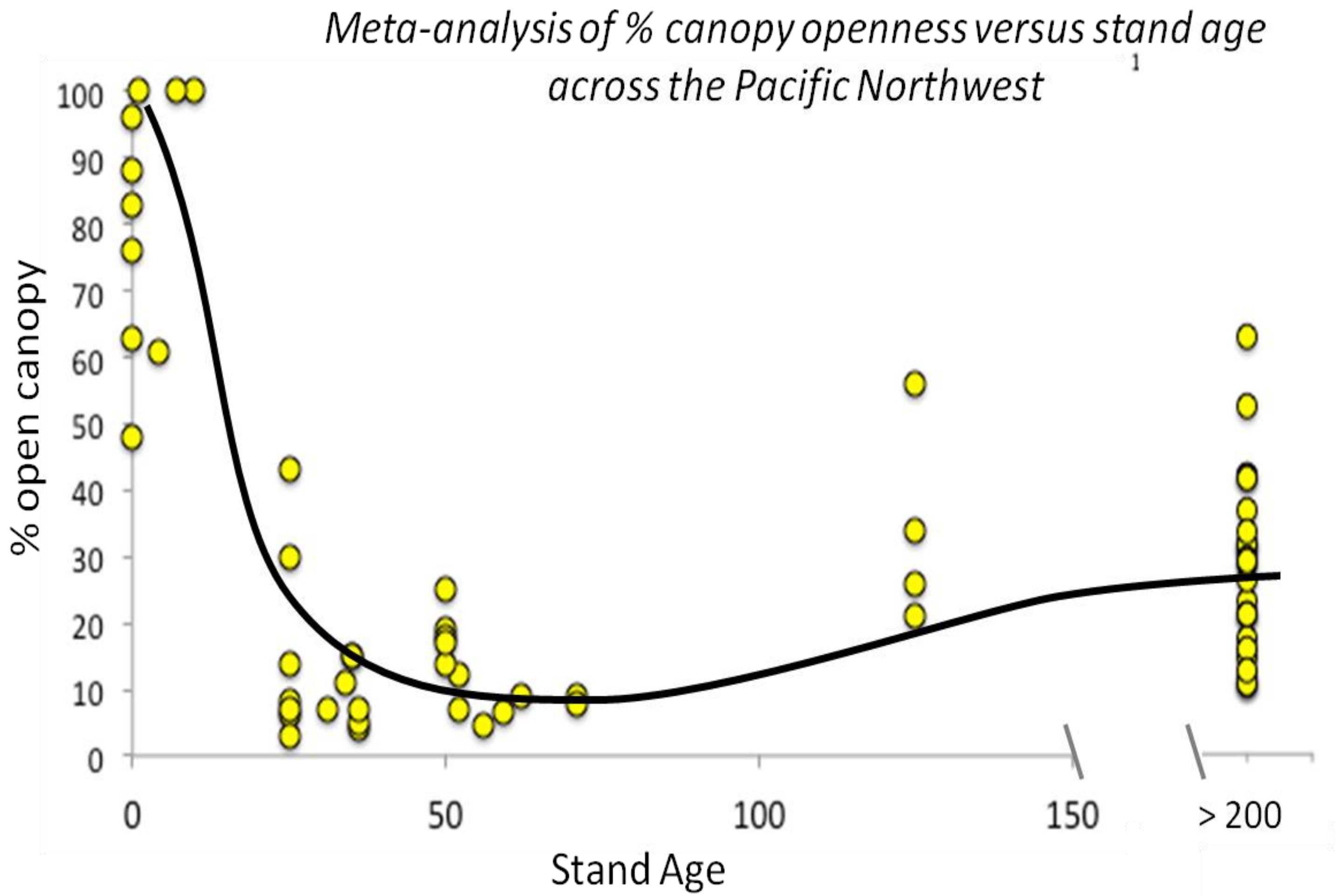


Riparian Canopy, Light and Temperature

Needle Branch, Alsea Watershed study
2^{nd} growth

Flynn Creek, Alsea Watershed study
150 year old stand

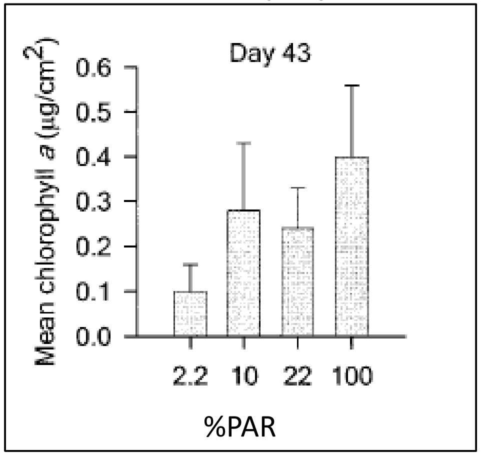
Canopy Openness (Light) and Stand Age



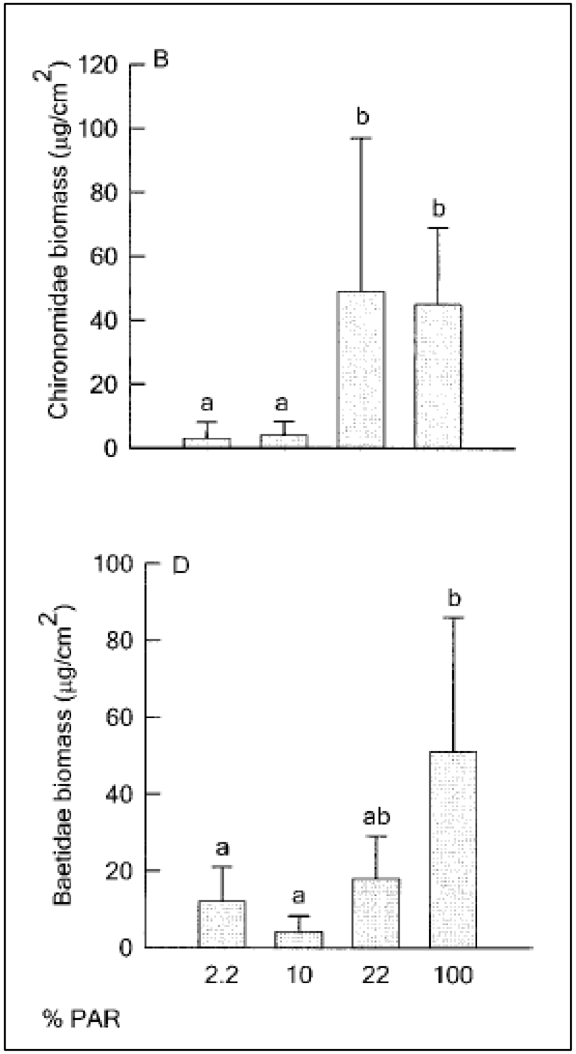
Nelson, et al., 2014

How Does Light Affect the Biota?

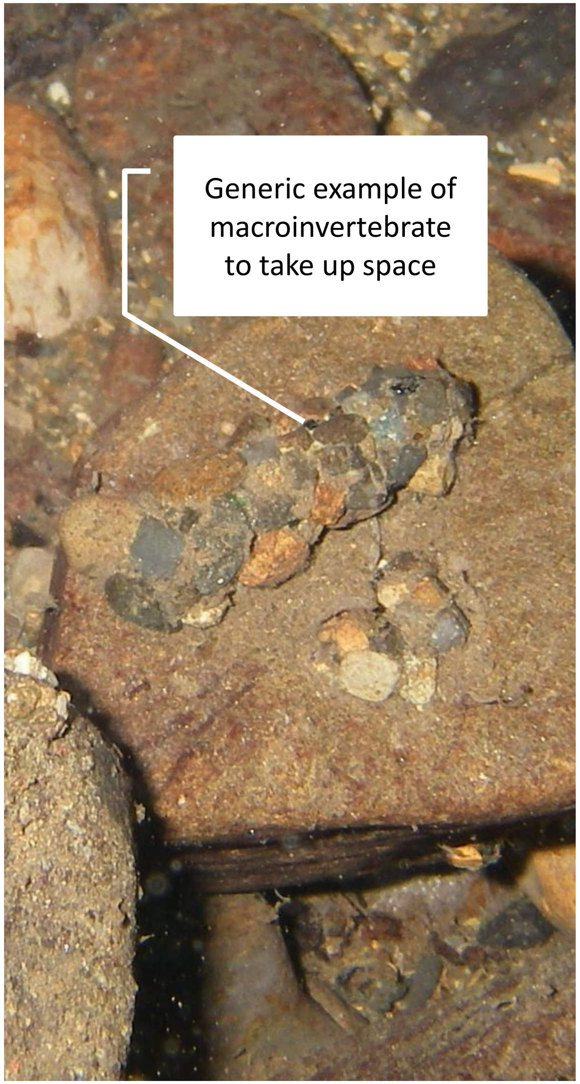
Chlorophyll



Macroinvertebrate biomass



Kiffney et al., 2004



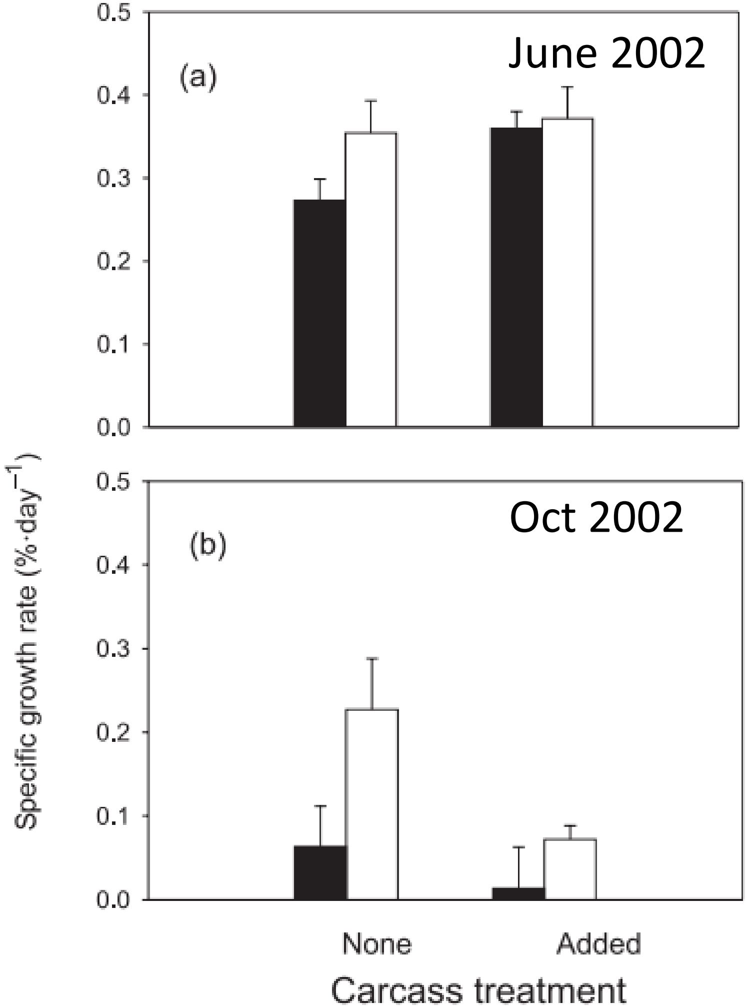
PAR= Photosynthetically Active Radiation
2.2 is equivalent to an unlogged basin, 10 is a 30 m buffer, 22 is a 10 m buffer and 100 is 100% open, i.e., no canopy remaining

Light Effects on Fish Growth

No. California experimental study of fish response to salmon carcass addition and reduction in riparian shade

Wilzbach et al. 2005

Higher Growth Rates with More Light



- Addition of salmon carcasses did not affect salmonid biomass, density, or growth.
- Removal of riparian canopy consistently enhanced salmonid biomass, density, and growth- except for young-of-the-year fish.

Fig. 4. Mean specific growth rates of yearling and older PIT tagged coastal cutthroat trout and rainbow trout recaptured in (a) June 2002, (b) October 2002 (solid bars, uncut riparian; open bars, cut riparian).

Wilzbach et al. 2005

Coho and Sunlight

"…prey resource availability and coho growth were associated with differences in canopy cover, with prey biomass and coho growth 2–4× higher in reaches receiving more sunlight".

Kiffney et al., 2014.

Microclimate: cool, moist habitat for biota

0-10 m from stream at 3 PM largest response, similar to other research in PNW

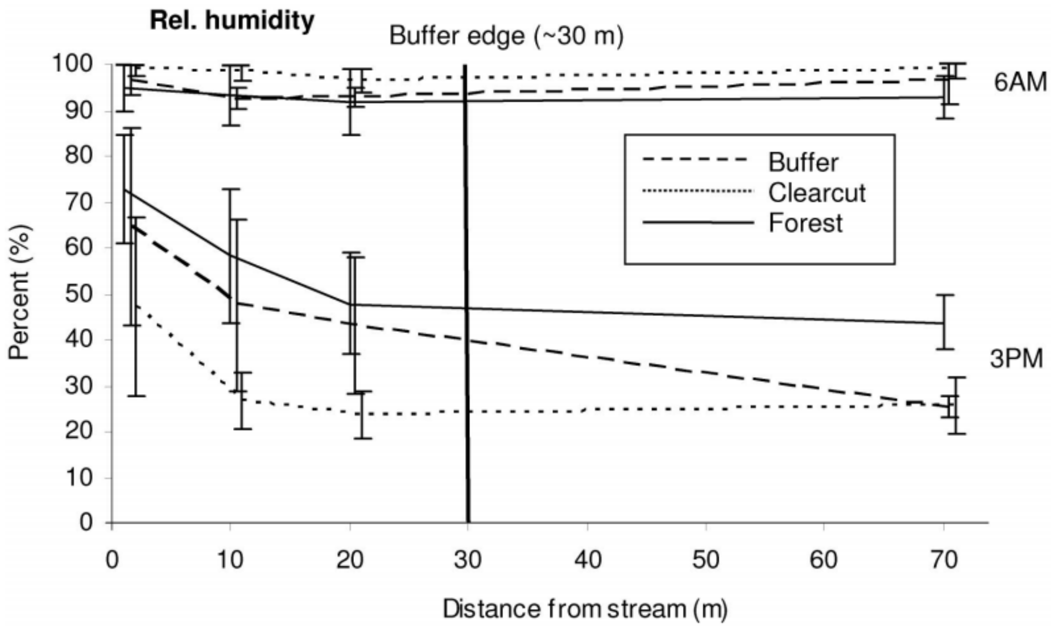


Figure 4. Mean relative humidity (±SD) at 6:00 am and at 3:00 pm in riparian buffer, clearcut, and forest treatments, between 1 and 70 m from the stream (treatments are slightly staggered along the *x* axis for clarity; *N* = 5, except in riparian buffer treatment at 1 m, *N* = 4). Location of the forest edge in the riparian buffer treatment is 24 to 35 m from the stream.

(Rykken et al., 2007)

Microclimate: FEMAT 1993 Update

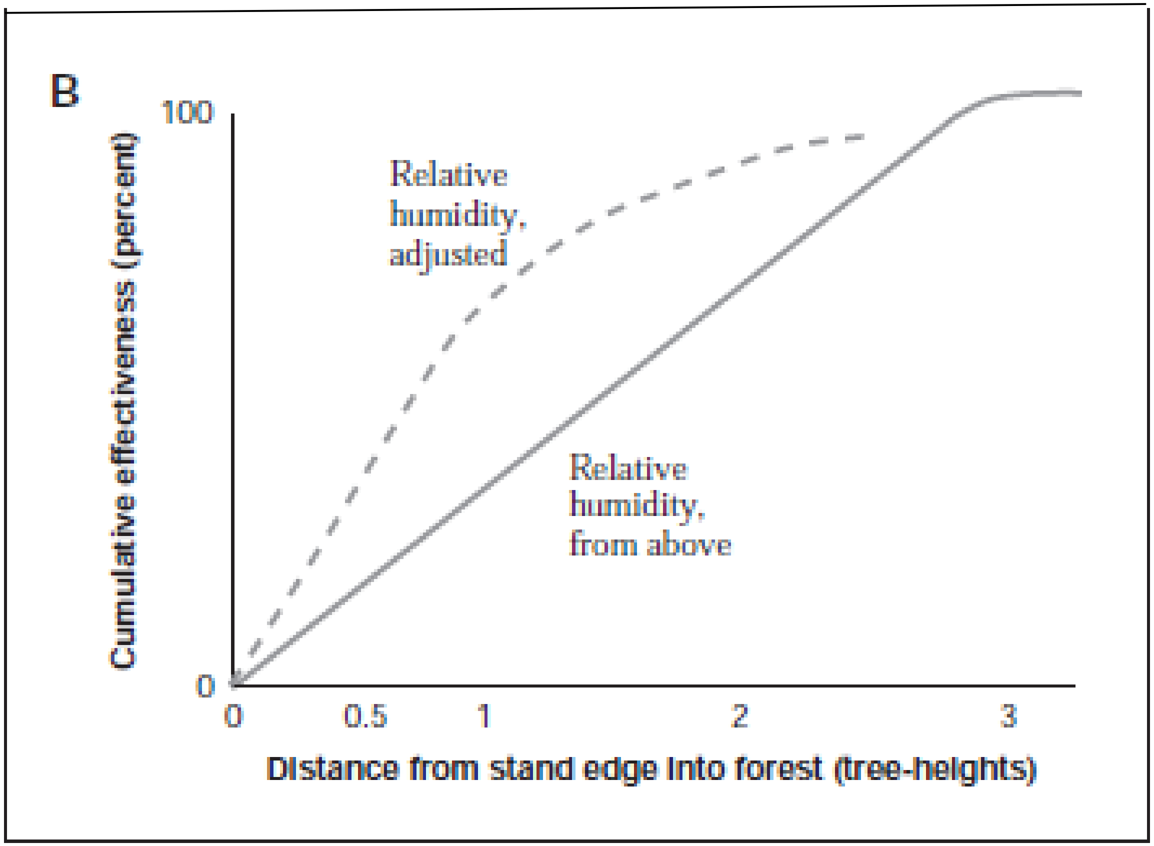
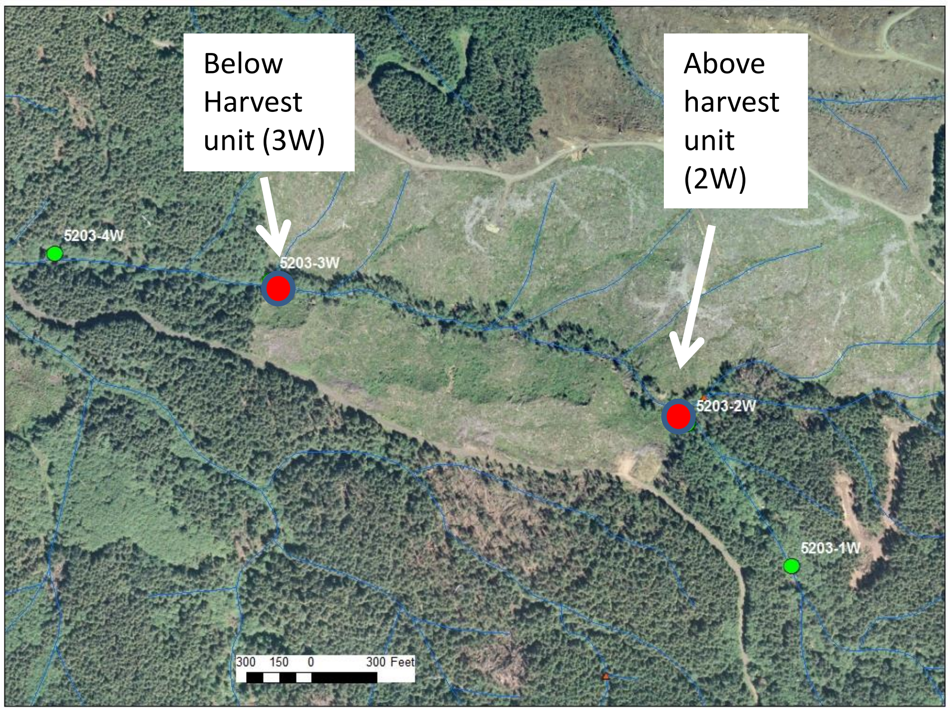


Figure 10—(A) Relation of distance from stream channel to cumulative effectiveness of factors influencing microclimate in riparian ecosystems. From FEMAT (1993, p. V-27); (B) Modified effectiveness curve for relative humidity as a function of distance from the stream channel. The curve was changed based on scientific literature developed since the original curve was portrayed in FEMAT (1993).

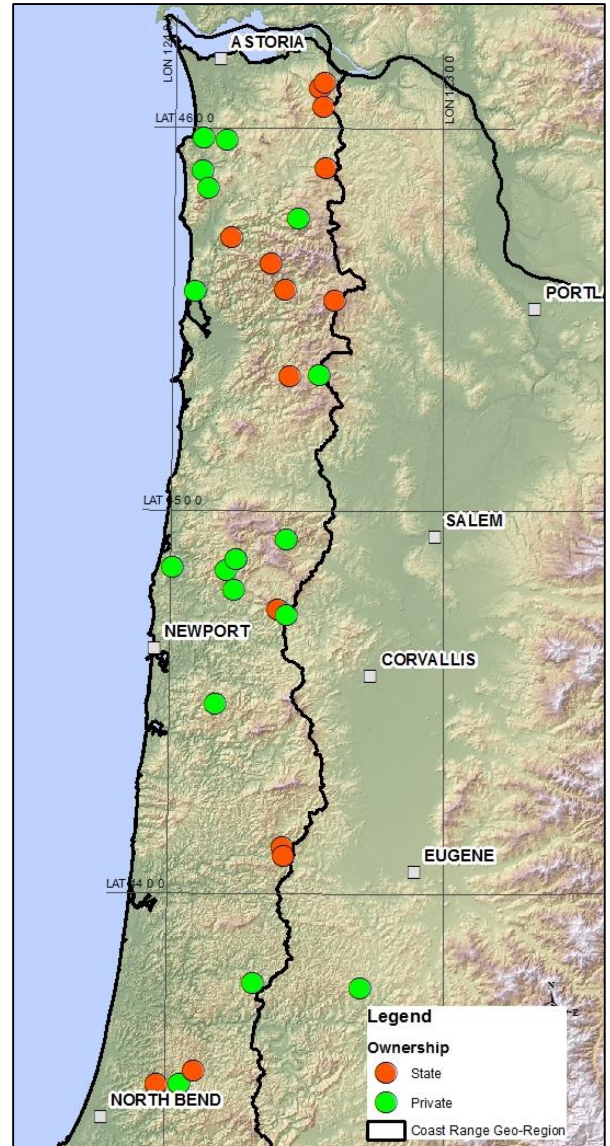
Reeves et al., 2016

Stream Temperature

- RipStream Study: Small and Medium fish-bearing streams on State and Private timberlands.



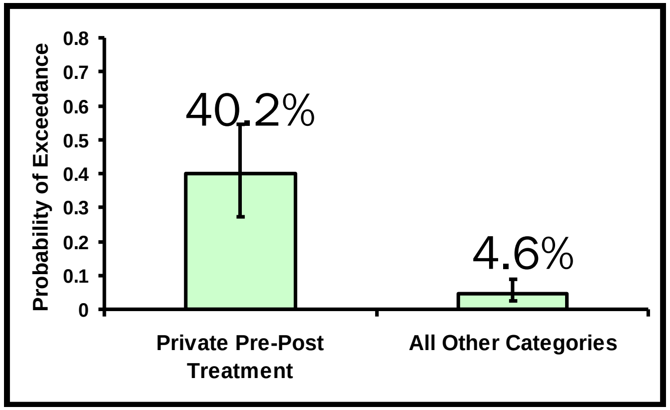
Private Site Example: 2-sided clearcut



Riparian Function: Keeping Streams Cold

Were streams warmed by more than 0.3 C (i.e., the Protecting Cold Water standard)?

Yes on private forest lands



How much did they warm and why?

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Response of western Oregon (USA) stream temperatures to contemporary forest management

Jeremiah D. Groom[a,*], Liz Dent[b], Lisa J. Madsen[c], Jennifer Fleuret[d]

[a] Department of Forest Engineering, Resources, and Management, Oregon State University, 204 Peavy Hall, Corvallis, OR 97331, USA
[b] Oregon Department of Forestry, 2600 State St., Salem, OR 97310, USA
[c] Department of Statistics, Oregon State University, 44 Kidder Hall, Corvallis, OR 97331, USA
[d] 923 W Pine St., Rawlins, WY 82301, USA

Results

- Private sites: temperature increased + 0.7 °C
- State sites: + 0.0 °C
- Temperature increases related to declines in shade

Longitudinal Changes in Stream Temperature

HYDROLOGICAL PROCESSES
Hydrol. Process. (2015)
Published online in Wiley Online Library
(wileyonlinelibrary.com) DOI: 10.1002/hyp.10641

Modelling temperature change downstream of forest harvest using Newton's law of cooling

Lawrence J. Davis,[1] Maryanne Reiter[2]* and Jeremiah D. Groom[3]

[1] *D3 Scientific, Springfield, OR, USA*
[2] *Weyerhaeuser Company, Springfield, OR, USA*
[3] *Oregon State University, Corvallis, OR, USA*

Abstract:

We adapted Newton's law of cooling to model downstream water temperature change in response to stream-adjacent forest harvest on small and medium streams (average 327 ha in size) throughout the Oregon Coast Range, USA. The model requires measured stream gradient, width, depth and upstream control reach temperatures as inputs and contains two free parameters, which were determined by fitting the model to measured stream temperature data. This model reproduces the measured downstream temperature responses to within 0.4 °C for 15 of the 16 streams studied and provides insight into the physical sources of site-to-site variation among those responses. We also use the model to examine how the pre-harvest to post-harvest change in daily maximum stream temperature depends on distance from the harvest reach. The model suggests that the pre-harvest to post-harvest temperature change approximately 300 m downstream of the harvest will range from roughly 82% to less than 1% of that temperature change that occurred within the harvest reach, depending primarily on the downstream width, depth and gradient. Using study-averaged values for these channel characteristics, the model suggests that for a stream representative of those in the study, the temperature change approximately 300 m downstream of the harvest will be 56% of the temperature change that occurred within the harvest reach. This adapted Newton's law of cooling procedure represents a highly practical means for predicting stream temperature behaviour downstream of timber harvests relative to conventional heat budget approaches and is informative of the dominant processes affecting stream temperature.

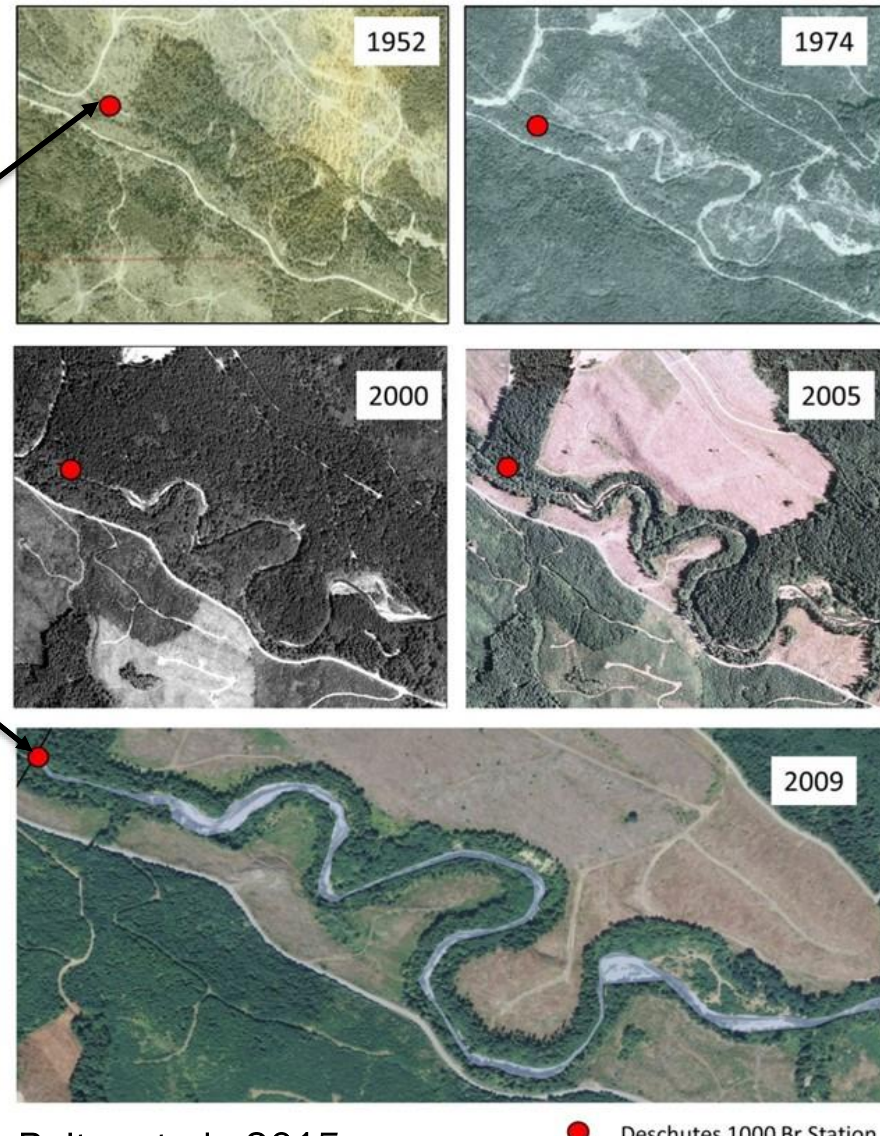
KEY WORDS stream temperature; Newton's law of cooling; downstream; timber harvest; temperature modelling

Received 19 May 2015; Accepted 9 August 2015

"…on average, pre- to post-changes in downstream temperature exist at roughly 50% of those changes in the harvest reach after ≈300m downstream, *but that they do not persist indefinitely*."

Davis et al., 2015

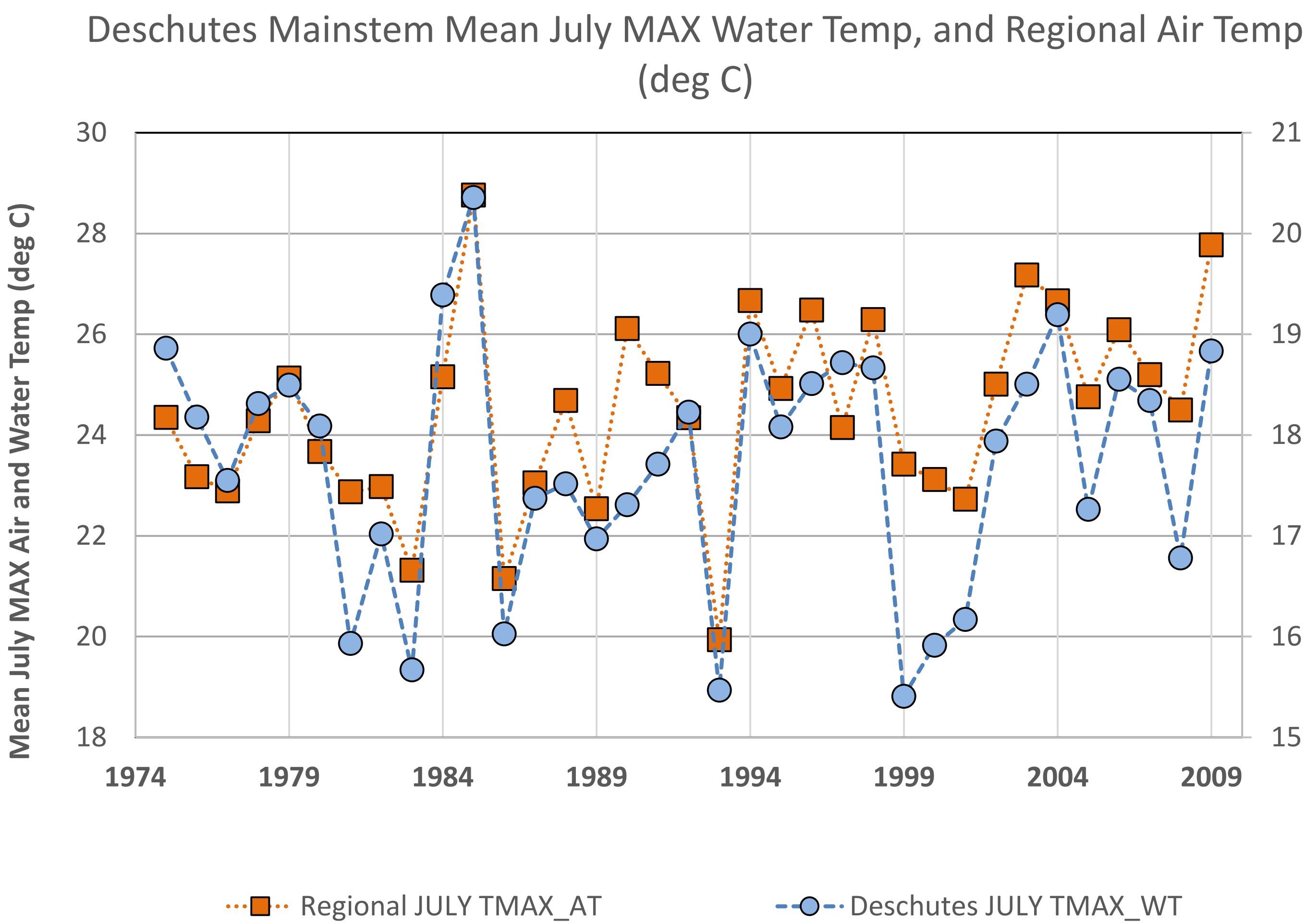
Riparian Buffers on Large Streams



On the Deschutes, 4 permanent monitoring stations were established in 1975 to measure suspended sediment, turbidity, streamflow, air and water temperature.

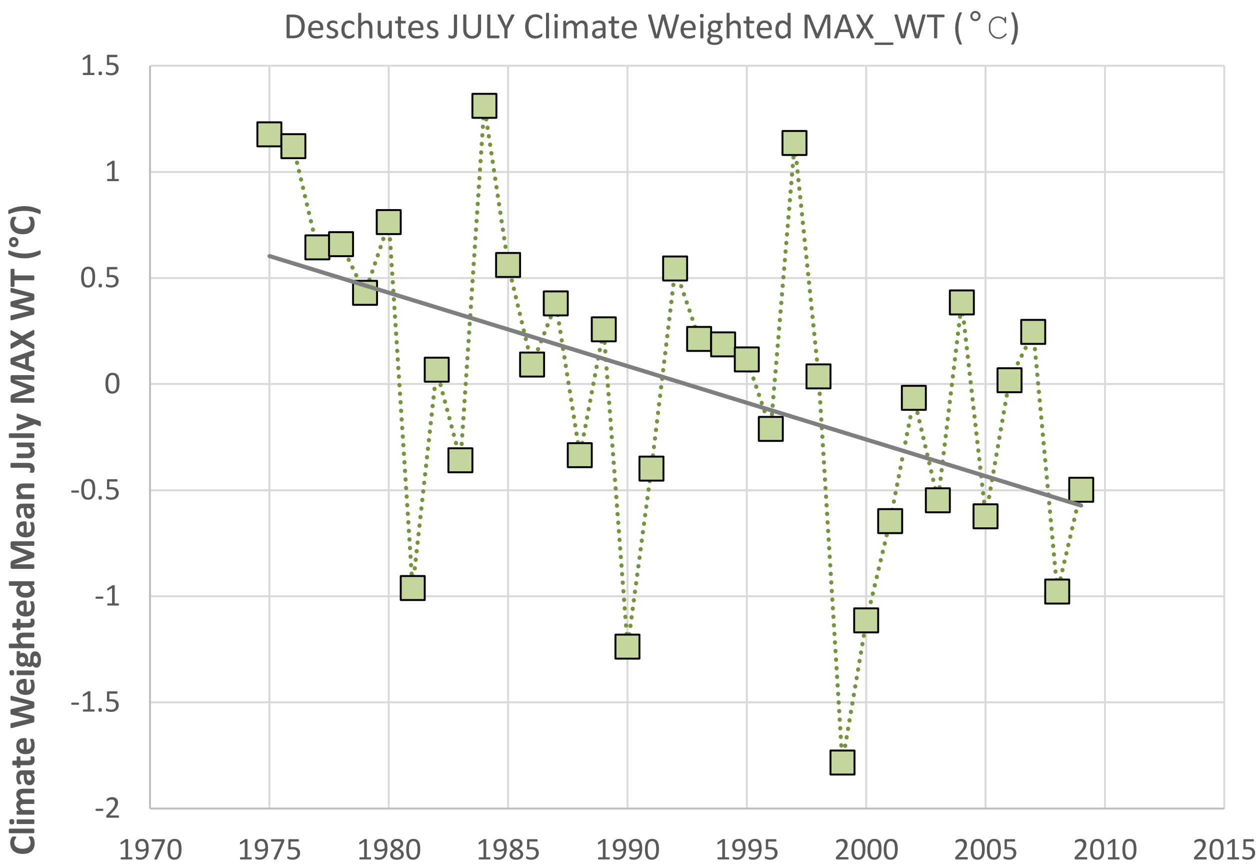
Reiter et al., 2015

Temp Changes Through Time on Large Streams



Air temperature trend = +0.07 °C/year Water temperature= no overall trend

Accounting for Climatic Variability



When we account for climate variability by fitting a model and examining the residuals, a different pattern emerges in stream temperatures. Mean July MAX water temperature has an overall decreasing trend of 0.04 °C/year.

Riparian Areas and Large Wood Recruitment

Large Wood Recruitment Processes

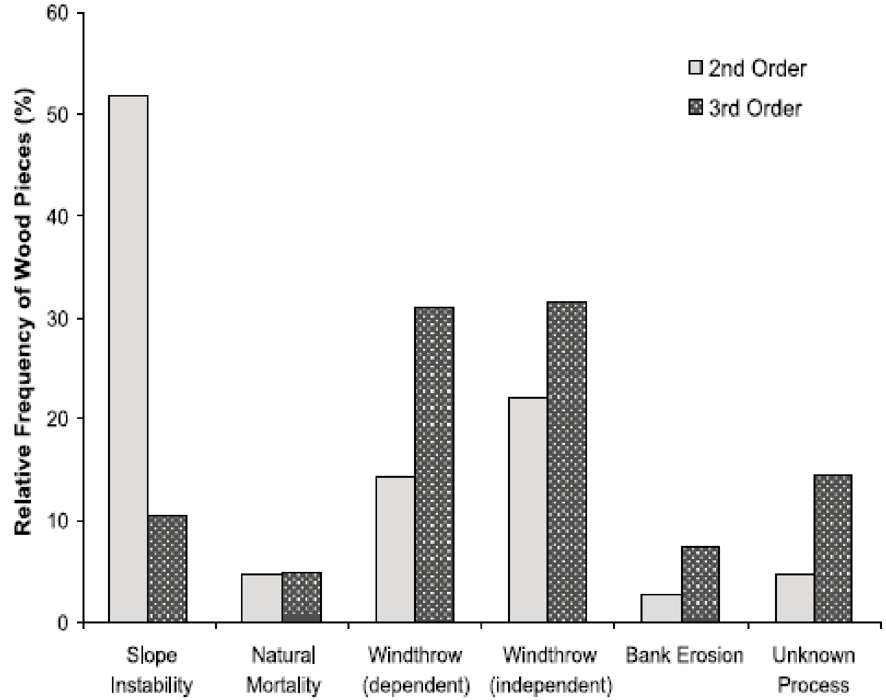
- Mortality (age, disease, fire)
- Blow down
- Bank erosion
- Landslides
- Snow avalanches

In steep landslide terrain, riparian recruitment accounts for only 35% of wood input. (Reeves et al., 2003).

Large Wood Recruitment Processes (cont.)

Unmanaged stands

Fig. 2. Wood delivered to colluvial (second-order) and alluvial (third-order) channels from different recruitment processes in the local hillslopes and riparian areas.



(May and Gresswell, 2003)

Riparian Recruitment and Stream Size

Recruitment Source Uncertainty

Large streams: source areas for ~48% of the wood pieces were found. (McDade et al., 1990)

Small, non-fish streams: could not find the source of 55% of the decayed wood in small streams. (Burton et al., 2016)

Large Wood: FEMAT Update

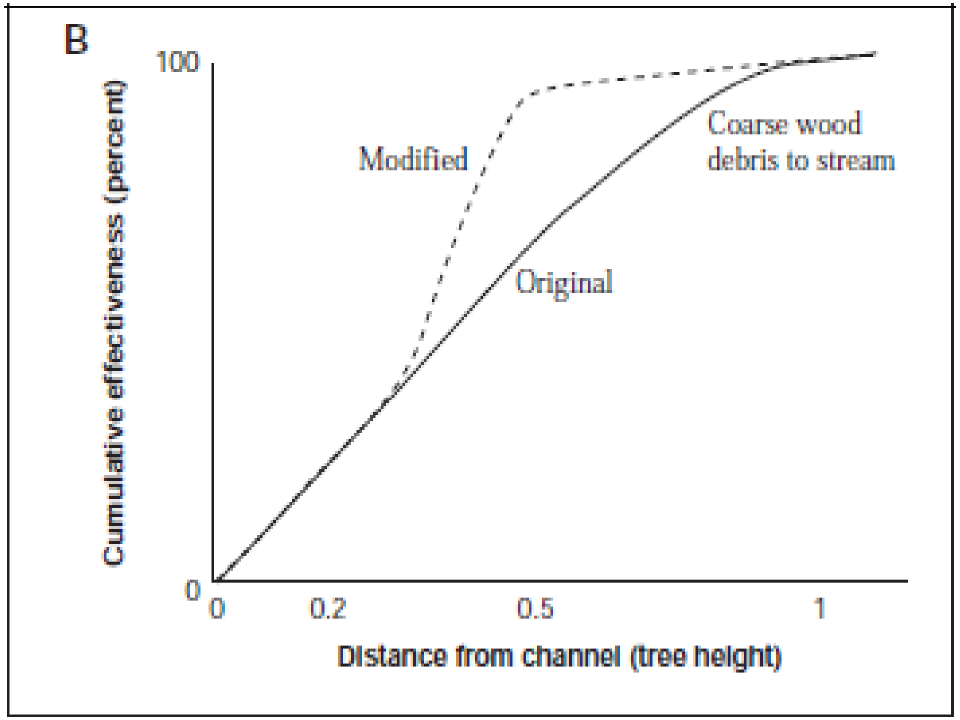
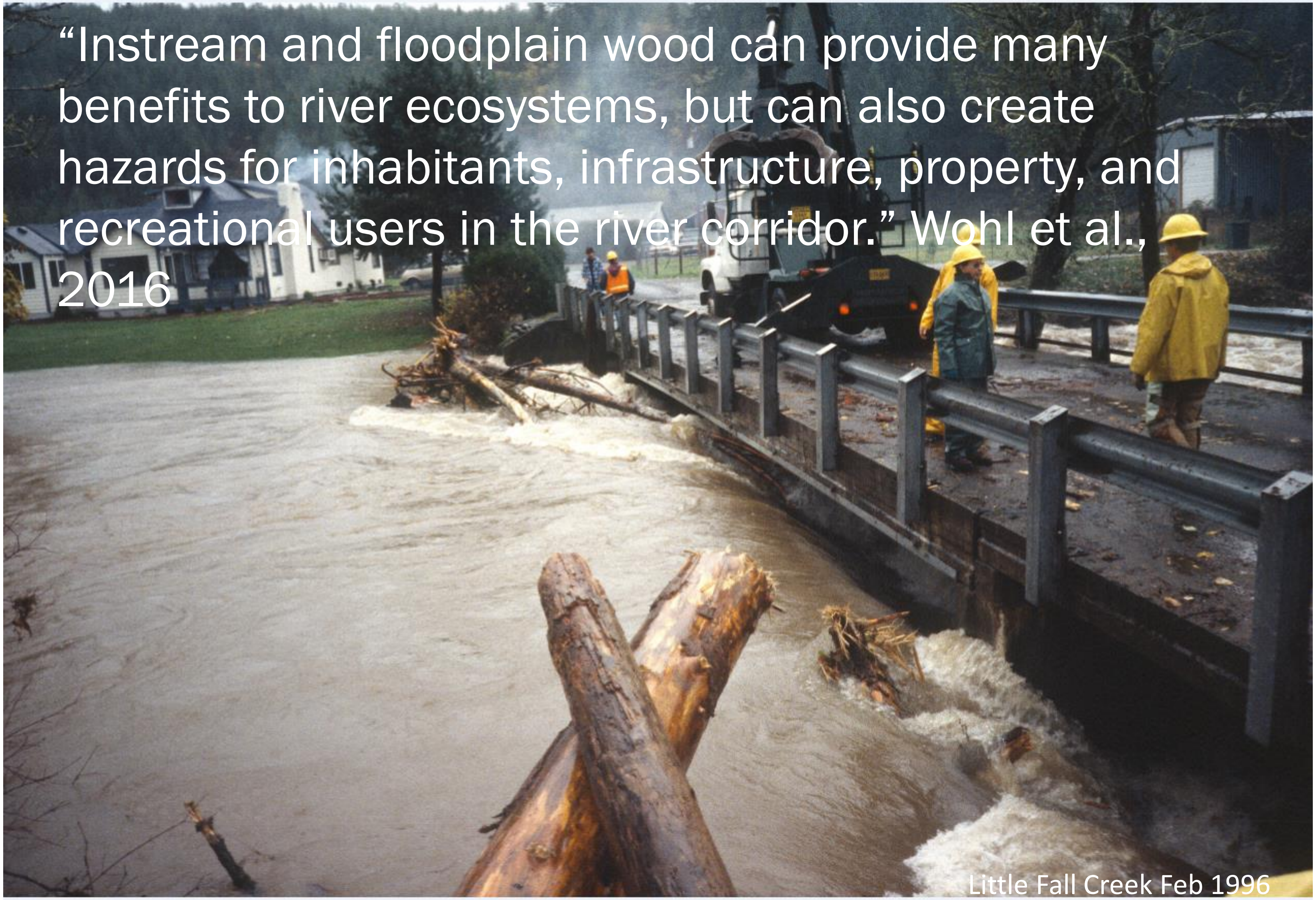


Figure 9—(A) Relation of distance from stream channel to cumulative effectiveness of riparian ecological functions. From: FEMAT (1993, p. V-27); (B) Modified effectiveness curve for wood delivery to streams as a function of distance from the stream channel. The curve was changed based on scientific literature developed since the original curve was portrayed in FEMAT (1993).

"Thus, more of the wood recruitment comes from the inner half of a site-potential tree-height than assumed in FEMAT…" Reeves et al., 2016

Large Wood and Public Safety



"Instream and floodplain wood can provide many benefits to river ecosystems, but can also create hazards for inhabitants, infrastructure, property, and recreational users in the river corridor." Wohl et al., 2016

Little Fall Creek Feb 1996

Large Wood and Public Safety

Organic Matter Inputs

"...physical structure alone will not restore invertebrate productivity without detrital resources from the riparian forest".

Wallace et al., 2015

OM Input Dependent on Species and Stand Age

Riparian forests dominated by red alder deliver greater amounts of annual litter to streams than those dominated by Douglas-fir (e.g., Hart et al., 2013).

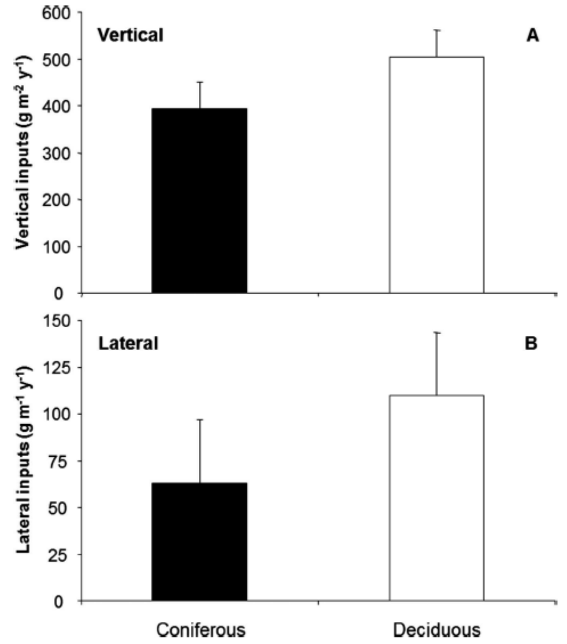
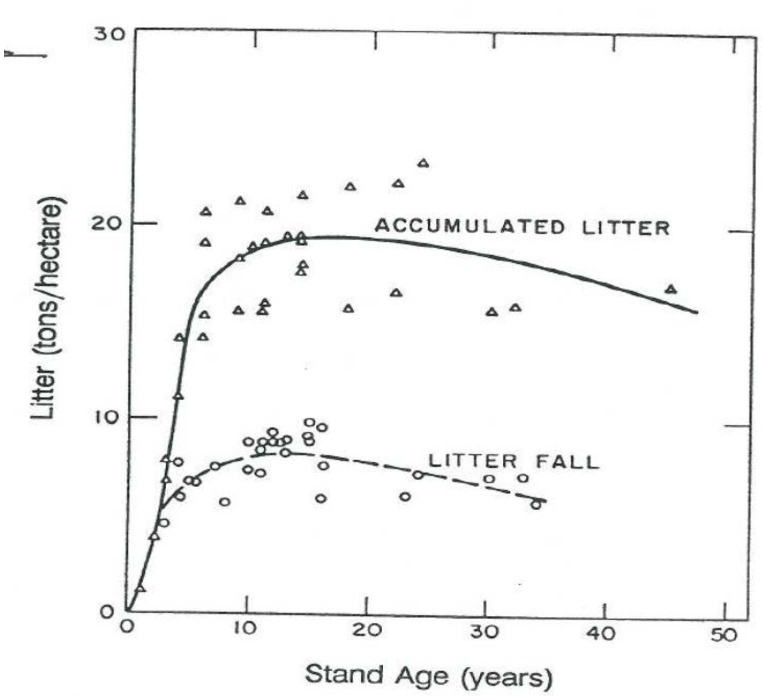


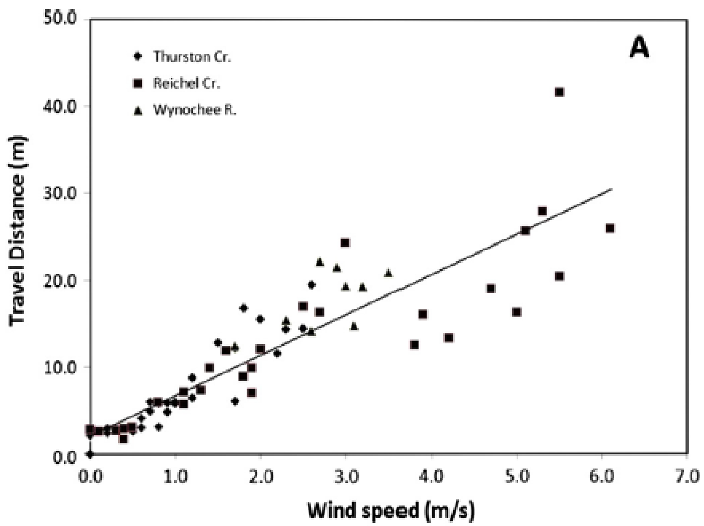
FIG. 2. Mean (95% CI) annual vertical (A) and lateral (B) litter input at deciduous and coniferous sites.



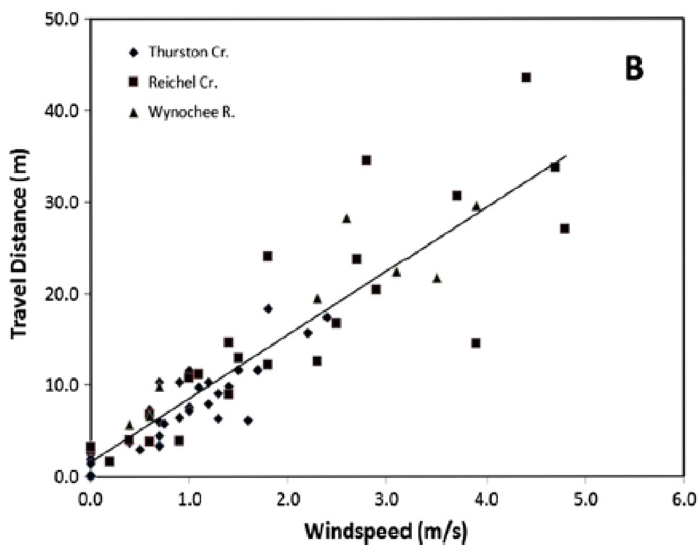
Alder litterfall increases the first 5 years and then levels off afterwards (Zavitkovski and Newton, 1971).

Organic Matter Input Processes

Needles



Red alder leaves



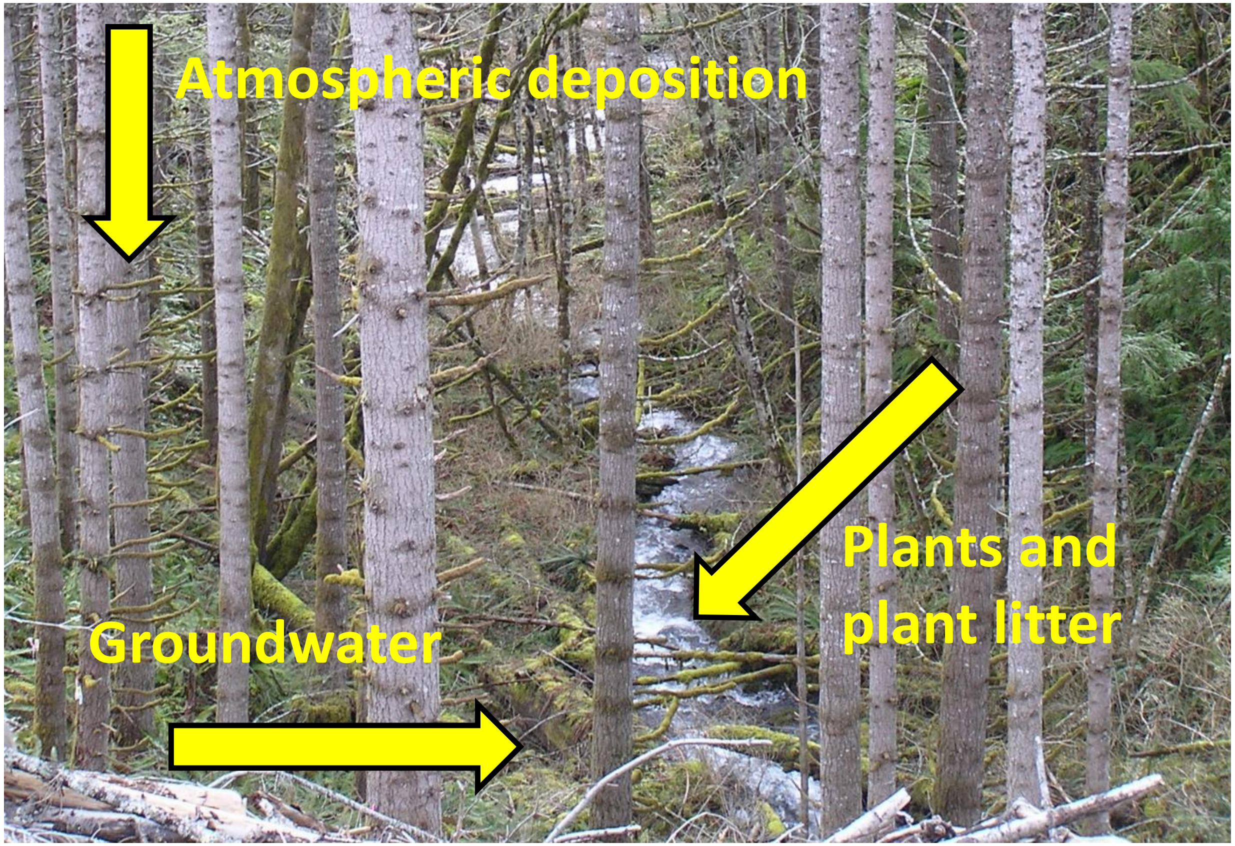
- Wind speed a dominant factor in determining transport distance
- Riparian characteristics such as forest age, stand composition and riparian topography can modify the relationship between wind speed and travel distance

Bilby and Heffner, 2016

Riparian Areas and Nutrients

USEPA considers nitrogen a stressor in aquatic systems.

Nitrogen stream entry pathways



Riparian areas can remove nitrate nitrogen through denitrification and plant uptake.

Riparian Areas and Nutrients

In a meta-analysis of several studies, Mayer et al., 2007 found that a small but significant proportion of nitrogen removal was explained by buffer width (R^2=0.09). The study indicated other factors than buffer width important including vegetation and depth of roots and flow paths.

Riparian Tree Species and Nutrient Cycling

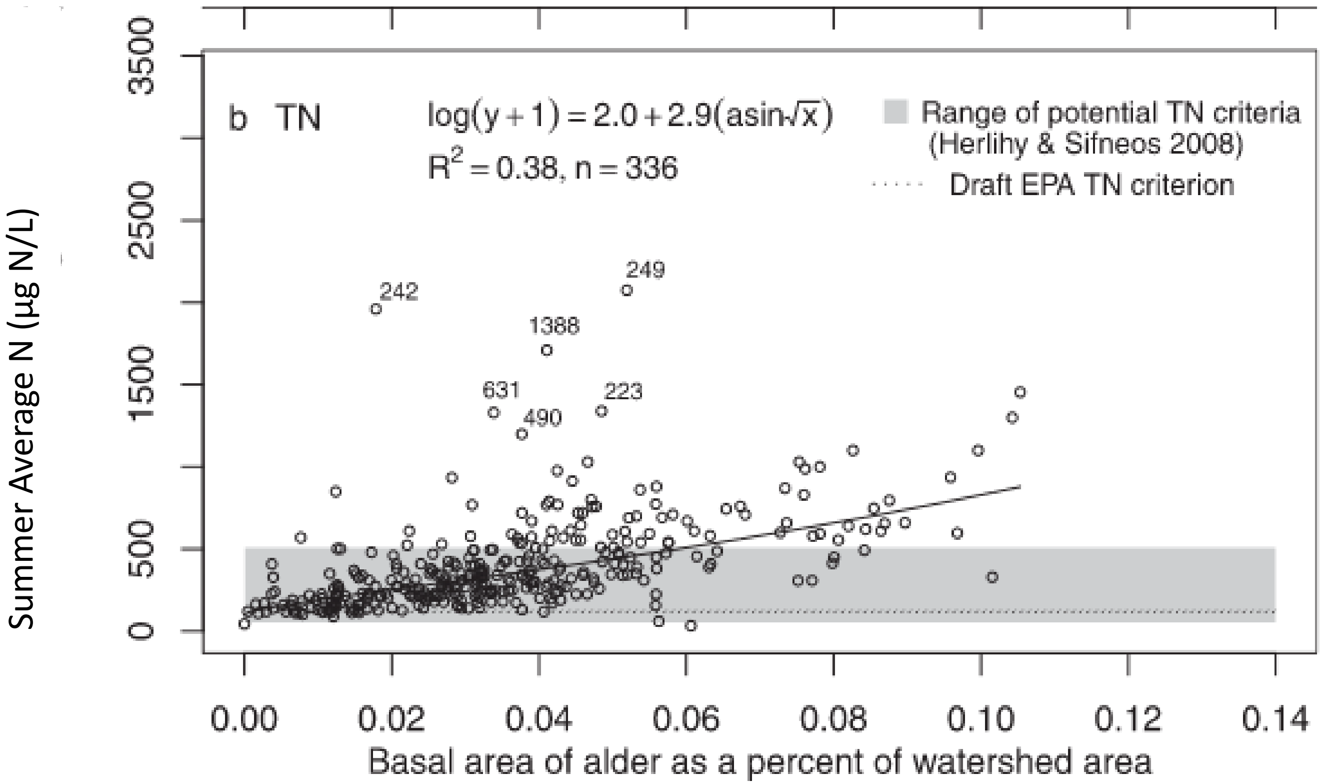
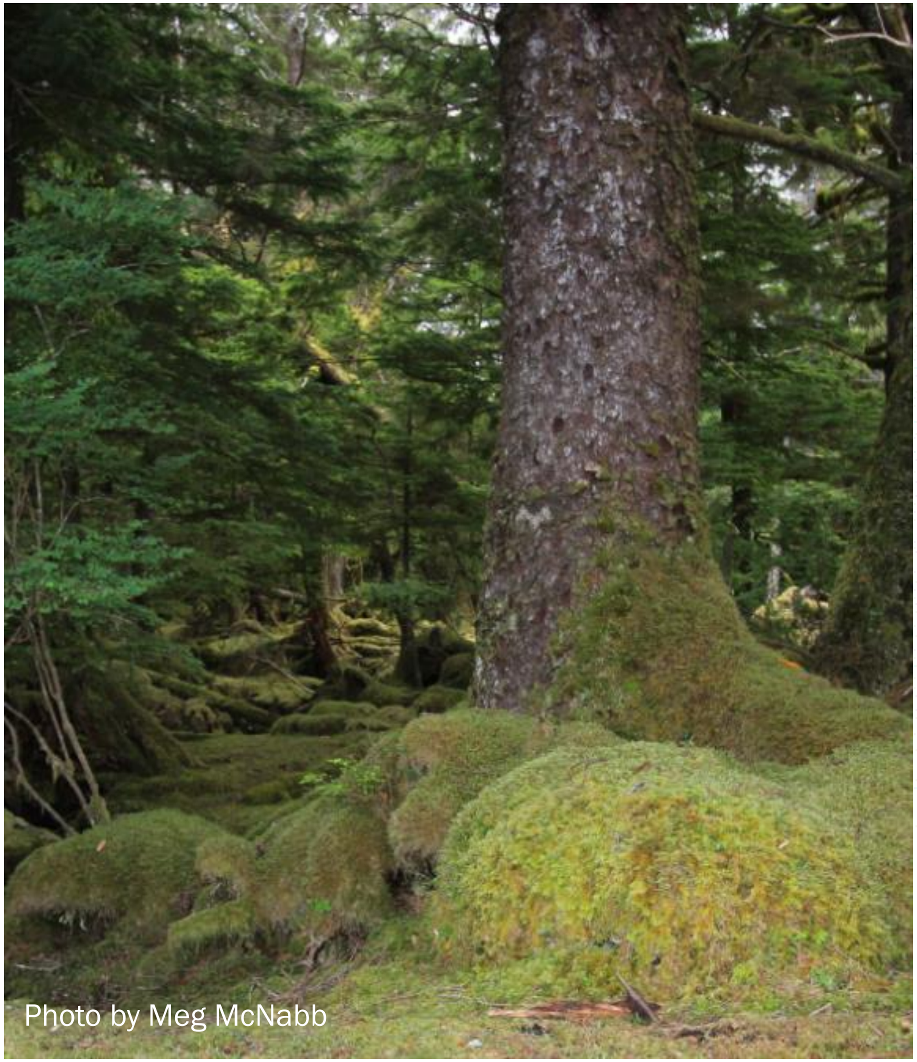


FIGURE 2. Average Summer NO_3-N, Average Summer TN, and Proposed Nutrient Criteria *vs*. Alder.

Greathouse et al. 2014 found a positive relationship between the % of a watershed in red alder and nitrogen.

Stream Subsidies to Riparian Trees



Sitka Spruce basal area growth per year

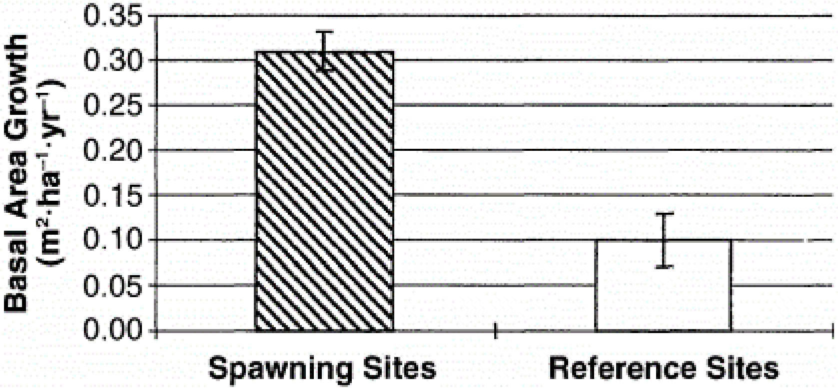
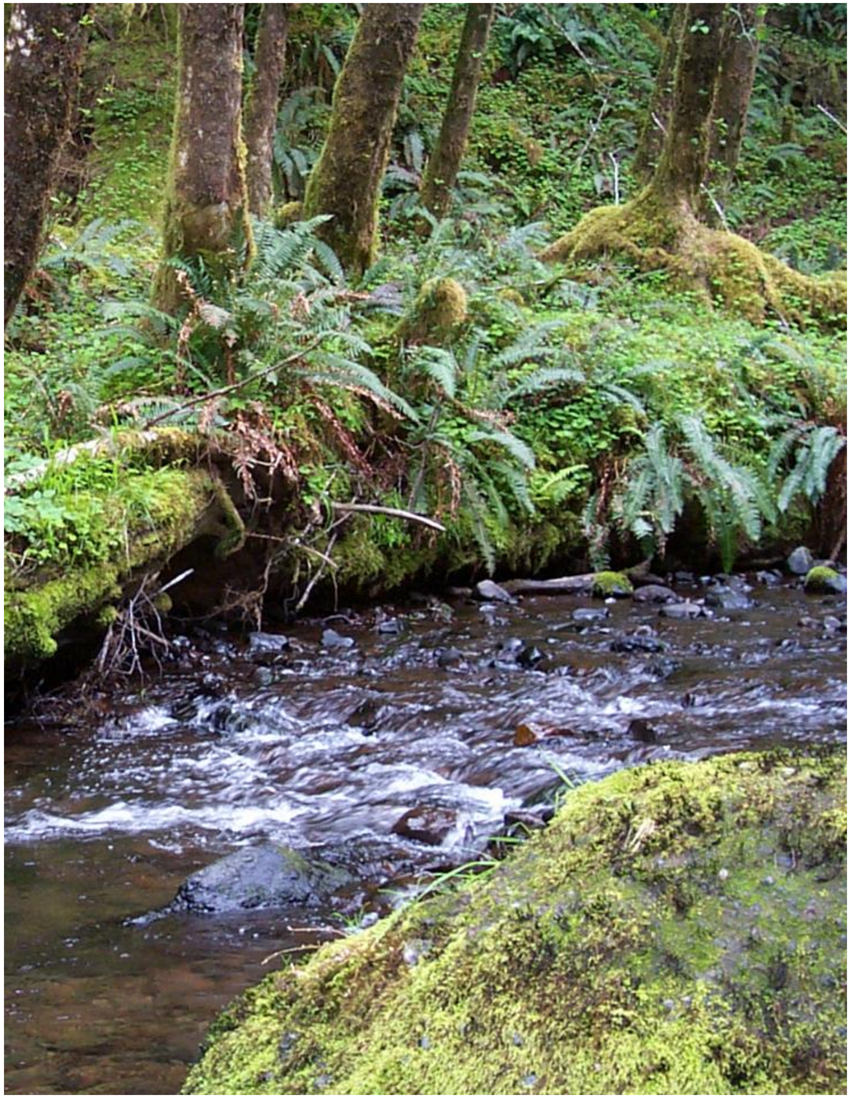


FIG. 4. Annual basal area growth per unit area of riparian Sitka spruce at spawning and reference sites. Values are means ± 1 SE.

(Helfield and Naiman, 2001)

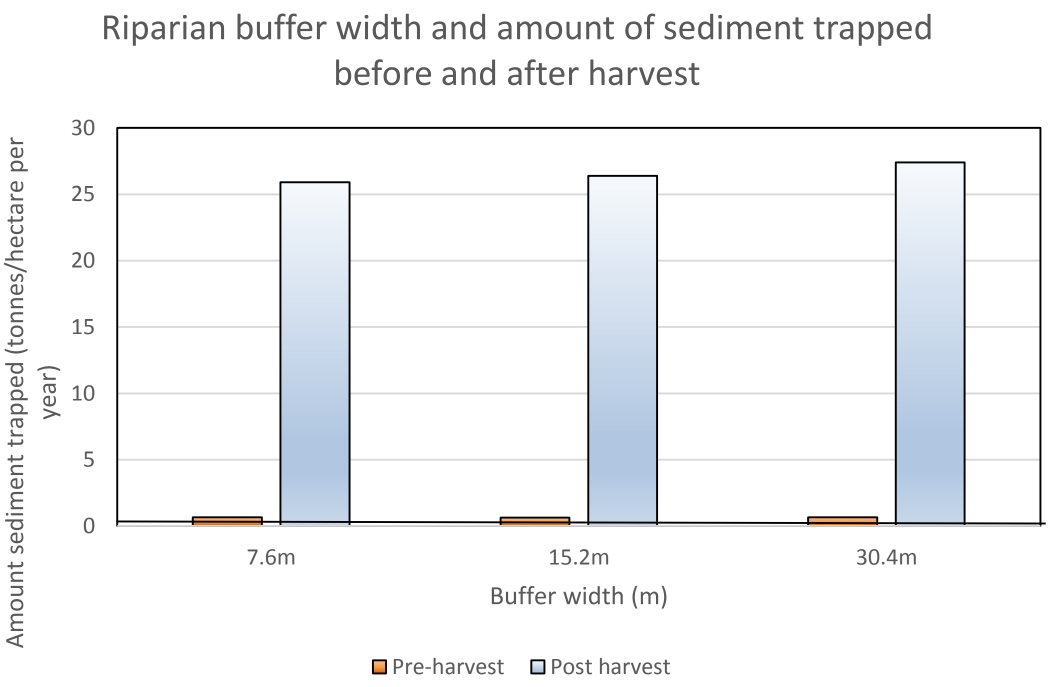
Bank Stability



The stability of streambanks is largely determined by the size, type, and cohesiveness of bank material, vegetation cover, and the amount of bedload carried by the channel (Sullivan et al., 1987).

Following a major flood in British Columbia, non-vegetated banks were 5 times more likely to experience erosion as compared to vegetated banks (Beeson and Doyle, 1995).

Sediment Filtration



(data modified from Lakel et al., 2010)

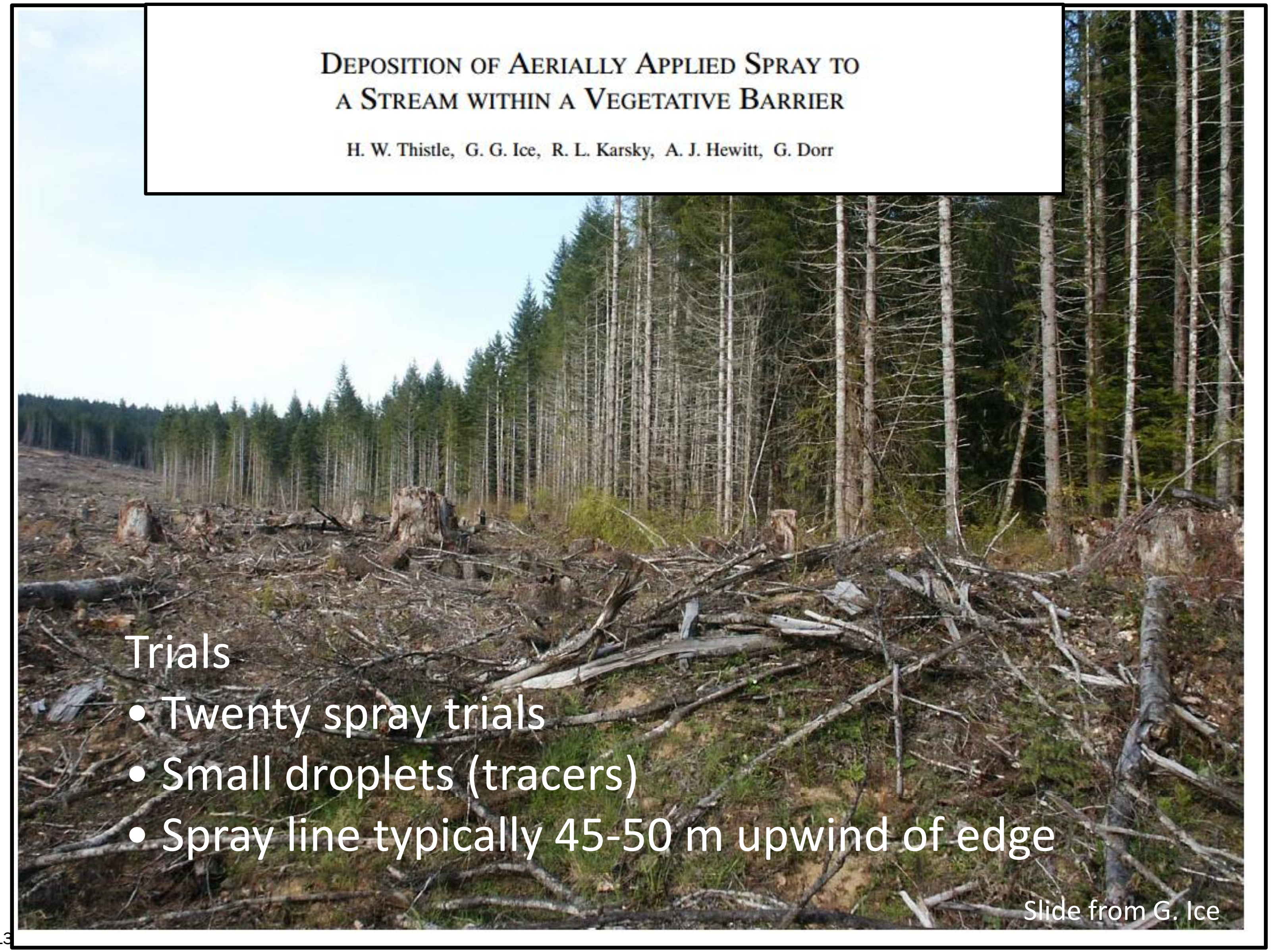
Sediment Filtration: Riparian Breakthrough

Channelized flow through riparian areas tended to occur in:

- convergent areas with large contributing areas
- high amounts amounts of bare ground
- steeper slopes

(Rivenbark and Jackson, 2004)

Chemical Filtration



Chemical Filtration (cont.)

Figure 2. Helicopter passing over sampler transects in front of riparian barrier.

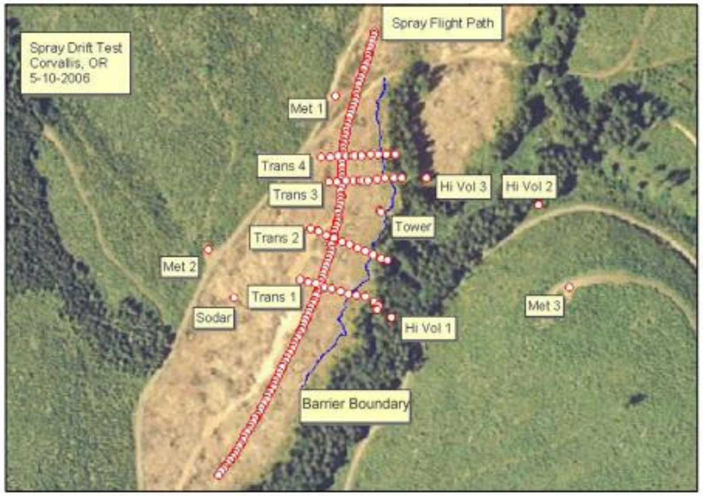


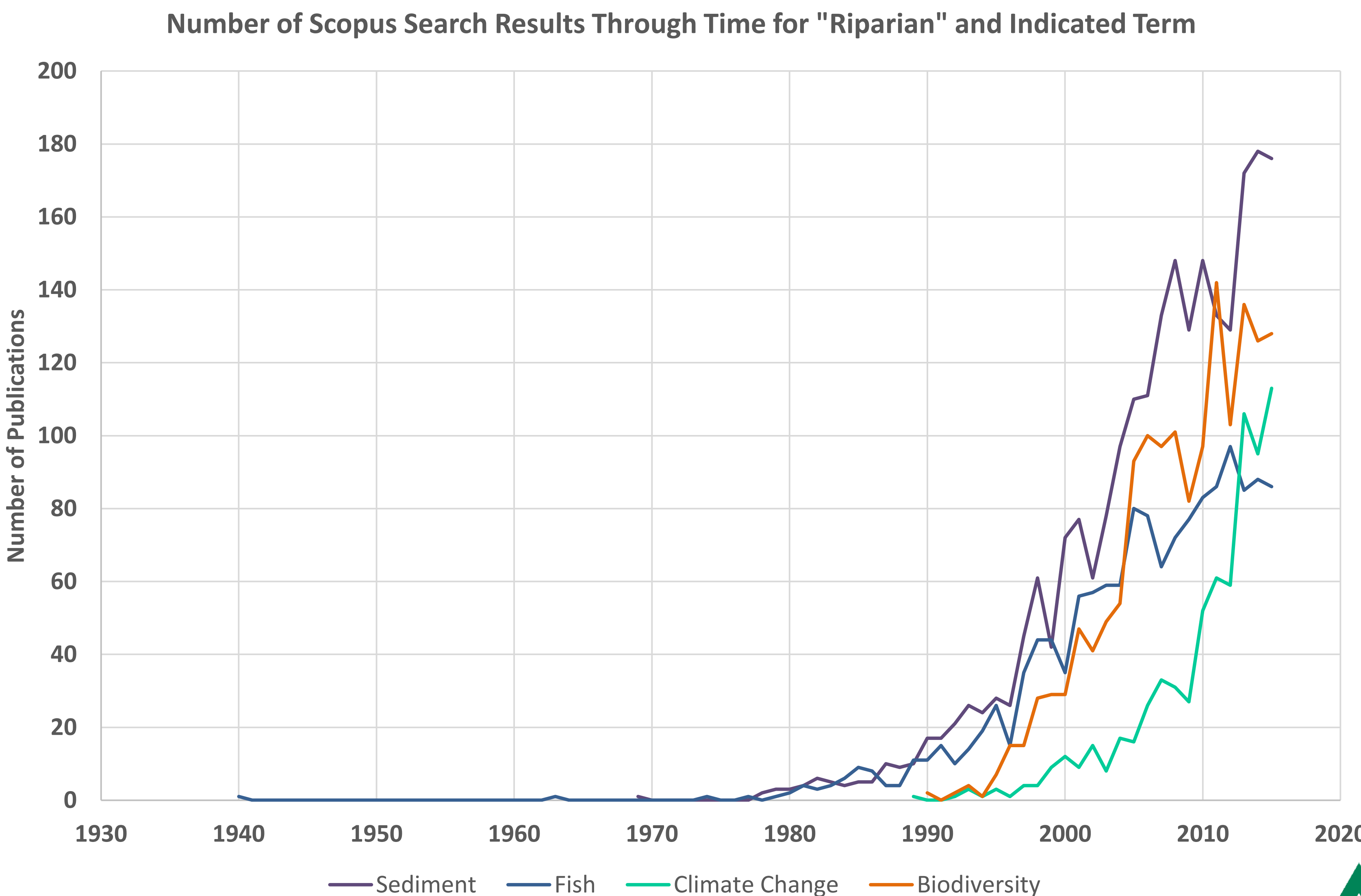
Figure 3. Aerial photo of the field site with sampling points, a typical flight path, and meteorological monitoring stations shown. For scale, transect 1 is 80 m long from beginning to end. The streams are roughly centered within the strip of mature forest, and the ground slopes downward toward the streams and generally downward toward the bottom of the photograph.

"This study demonstrates that riparian barriers prevent a substantial portion of airborne droplets from depositing into streams".

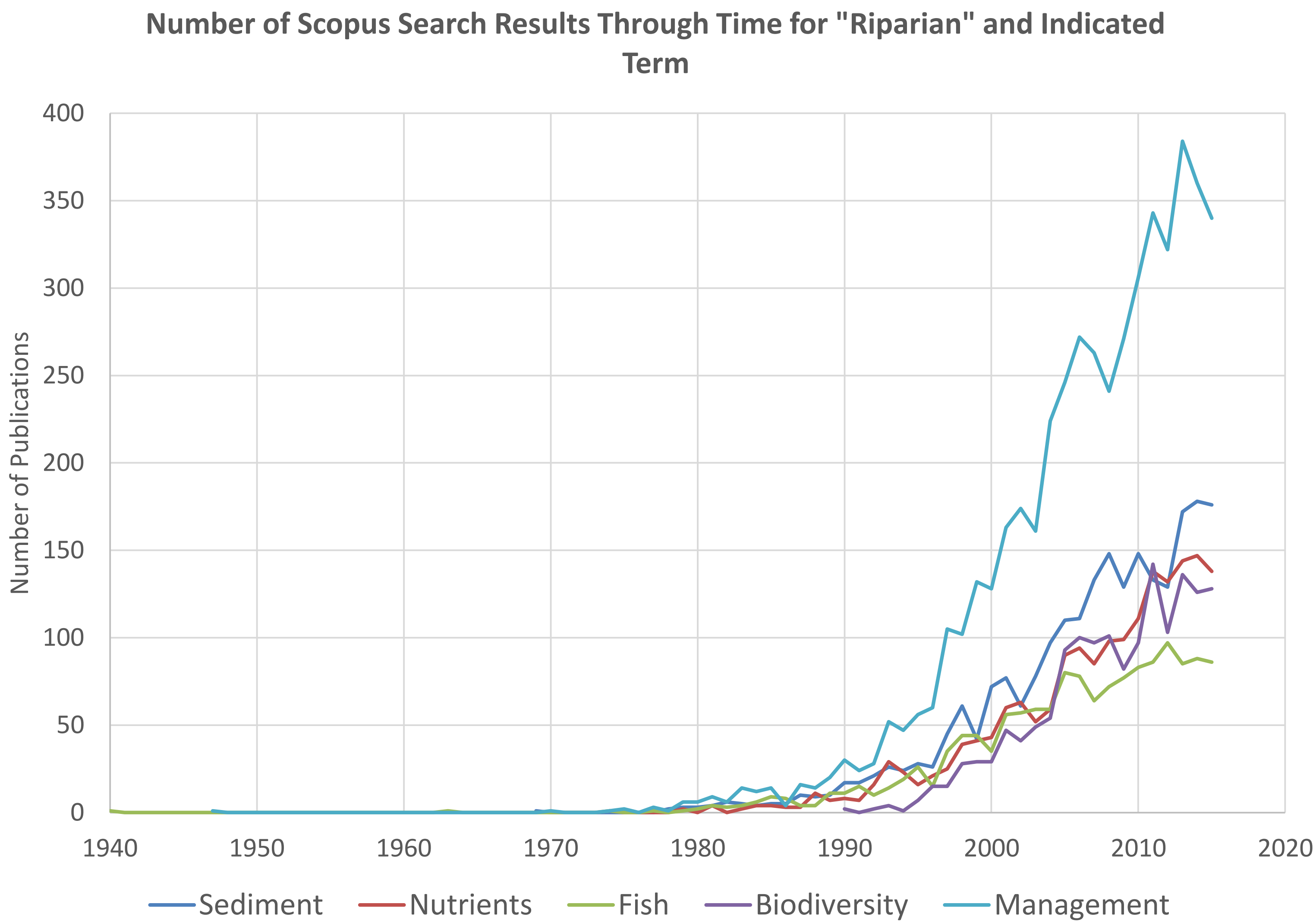
They measured reductions ranging from 58 to 96% of the fine droplet (driftable) fraction when compared to modeled controls.

Thistle et al. 2009.

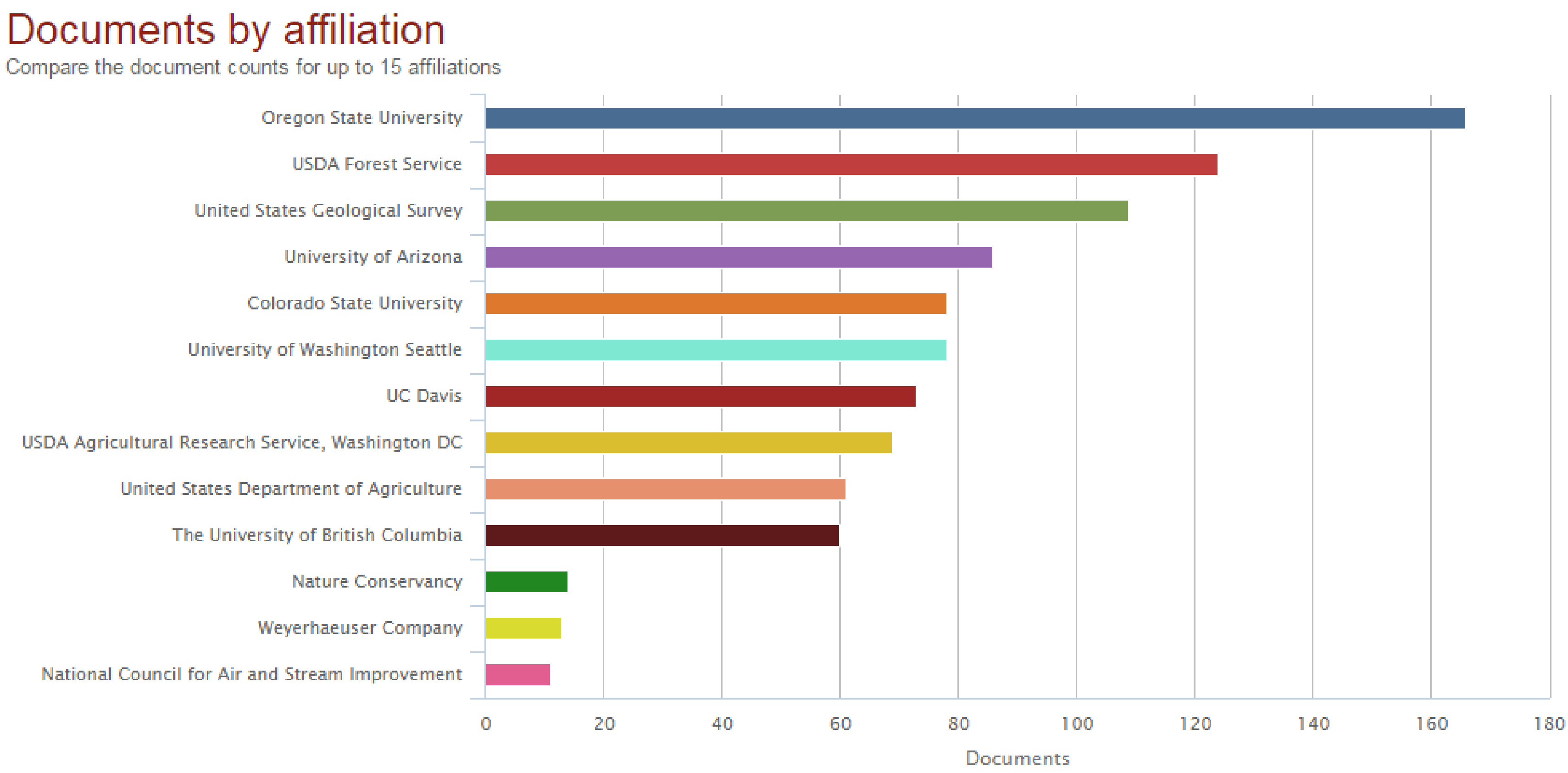
Future Focus on Riparian Functions



Riparian Function and Management



Riparian Management Research



Summary

- We have learned a significant amount about the functions of riparian areas in the last several decades.
- Some functions occur closer to the stream than initially thought, e.g., microclimate, though in the case of wood, a significant amount can come from farther away in the watershed.
- Regulations may sometimes be at odds with ecological function (e.g., no measurable stream temperature increase vs. light and nutrient criteria below natural conditions).
- Future focus on riparian areas include biodiversity, climate change and ecological services, all of which are difficult to quantify.

Questions?

Literature Cited

Beeson, C.E. and Doyle, P.F., 1995. Comparison of bank erosion at vegetated and non-vegetated channel bends. J*ournal of the American Water Resources Association* 31, no. 6 : 983-990

Bilby, R.E. and Heffner, J.T., 2016. Factors influencing litter delivery to streams. *Forest Ecology and Management*, *369*, pp.29-37.

Burton, J.I., Olson, D.H. and Puettmann, K.J., 2016. Effects of riparian buffer width on wood loading in headwater streams after repeated forest thinning. *Forest Ecology and Management*, *372*, pp.247-257.

Castelle ,A.J. and A.W. Johnson. 2000.. *Riparian vegetation effectiveness.* National Council for Air and Stream Improvement, Inc. Technical Bulletin No. 799. Research Triangle Park, NC: NCASI.

Davis, L.J., Reiter, M. and Groom, J.D., 2015. Modelling temperature change downstream of forest harvest using Newton's law of cooling. *Hydrological Processes*.

D'Souza, L.E., Reiter, M., Six, L.J. and Bilby, R.E., 2011. Response of vegetation, shade and stream temperature to debris torrents in two western Oregon watersheds. *Forest Ecology and Management*, *261*(11), pp.2157-2167.

Greathouse, E.A., Compton, J.E. and Van Sickle, J., 2014. Linking landscape characteristics and high stream nitrogen in the Oregon Coast range: Red alder complicates use of nutrient criteria. *JAWRA Journal of the American Water Resources Association*, *50*(6), pp.1383-1400.

Groom, J.D., Dent, L. and Madsen, L.J., 2011a. Stream temperature change detection for state and private forests in the Oregon Coast Range. *Water Resources Research*, *47*(1).

Groom, J.D., Dent, L., Madsen, L.J. and Fleuret, J., 2011b. Response of western Oregon (USA) stream temperatures to contemporary forest management. *Forest Ecology and Management*, *262*(8), pp.1618-1629.

Hart, S.K., Hibbs, D.E. and Perakis, S.S., 2013. Riparian litter inputs to streams in the central Oregon Coast Range. *Freshwater Science*, *32*(1), pp.343-358.

Helfield, J.M. and R. J. Naiman. 2001. Effects of Salmon-Derived Nitrogen on Riparian Forest Growth and Implications for Stream Productivity Ecology, Vol. 82 (9): 2403-2409

Literature Cited (cont.)

Kiffney, P.M., Richardson, J.S. and Bull, J.P., 2004. Establishing light as a causal mechanism structuring stream communities in response to experimental manipulation of riparian buffer width. *Journal of the North American Benthological Society*, *23*(3), pp.542-555.

Kiffney, P.M., Buhle, E.R., Naman, S.M., Pess, G.R. and Klett, R.S., 2014. Linking resource availability and habitat structure to stream organisms: an experimental and observational assessment. *Ecosphere*, *5*(4), pp.1-27.

Lakel, W.A., Aust, W.M., Bolding, M.C., Dolloff, C.A., Keyser, P. and Feldt, R., 2010. Sediment trapping by streamside management zones of various widths after forest harvest and site preparation. *Forest Science*, *56*(6), pp.541-551.

Martin, D.J. and Benda, L.E., 2001. Patterns of instream wood recruitment and transport at the watershed scale. *Transactions of the American Fisheries Society*, *130*(5), pp.940-958.

May, C.L. and Gresswell, R.E., 2003. Large wood recruitment and redistribution in headwater streams in the southern Oregon Coast Range, USA. *Canadian Journal of Forest Research*, *33*(8), pp.1352-1362.

Mayer, P.M., Reynolds, S.K., McCutchen, M.D. and Canfield, T.J., 2007. Meta-analysis of nitrogen removal in riparian buffers. *Journal of environmental quality*, *36*(4), pp.1172-1180.

McDade, M. H., F. J. Swanson, W. A. McKee, and J. Van Sickle. 1990. Source distances for coarse woody debris entering small streams in western Oregon and Washington. Can. J. For. Res. 20(3):326-330.

Nelson, Michael; Warren D., Arismendi I. 2014. Riparian forest structure and bottom-up drivers of fish production in headwater streams, presentation for Fish and Wildlife Habitat in Managed Forests Research Program at http://www.forestry.oregonstate.edu/fish-and-wildlife-habitat-managed-forests-research-program

Reeves, G.H., Burnett, K.M. and McGarry, E.V., 2003. Sources of large wood in the main stem of a fourth-order watershed in coastal Oregon.*Canadian Journal of Forest Research*, *33*(8), pp.1363-1370.

Reeves, G.H., Pickard, B.R. and Johnson, K.N., 2016. An initial evaluation of potential options for managing riparian reserves of the Aquatic Conservation Strategy of the Northwest Forest Plan.

Literature Cited (cont.)

Reiter, M., Bilby, R.E., Beech, S. and Heffner, J., 2015. Stream temperature patterns over 35 years in a managed forest of western Washington. *JAWRA Journal of the American Water Resources Association*, *51*(5), pp.1418-1435.

Rivenbark, B.L. and Rhett Jackson, C., 2004. Concentrated Flow Breakthroughs Moving Through Silvicultural Streamside Management Zones: Southeastern Piedmont, USA. *Journal of the American Water Resources Association*, *40*, pp.1043-1052.

Rykken, J.J., Chan, S.S. and Moldenke, A.R., 2007. Headwater riparian microclimate patterns under alternative forest management treatments.*Forest Science*, *53*(2), pp.270-280.

Sullivan, K., T. E. Lisle, C. A. Dolloff, G. E. Grant, and L. M. Reid. 1987. Stream channels: the link between the forests and fishes., p. 39-97. In E.O. Salo and T.W. Cundy (eds.) Streamside Management: Forestry and Fisheries Interactions. Institute of Forest Resources, University of Washington, Seattle, WA. 471 pp.

Sweeney, B. W. and J. D. Newbold, 2014. Streamside Forest Buffer Width Needed to Protect Stream Water Quality, Habitat, and Organisms: A Literature Review. Journal of the American Water Resources Association (JAWRA) 50(3): 560-584. DOI: 10.1111/jawr.12203

Thistle, H.W., Ice, G.G., Karsky, R.L., Hewitt, A.J. and Dorr, G., 2009. Deposition of aerially applied spray to a stream within a vegetative barrier.*Transactions of the ASABE*, *52*(5), pp.1481-1490.

Wallace, J.B., Eggert, S.L., Meyer, J.L. and Webster, J.R., 2015. Stream invertebrate productivity linked to forest subsidies: 37 stream-years of reference and experimental data. *Ecology*, *96*(5), pp.1213-1228.

Wilzbach, M.A., Harvey, B.C., White, J.L. and Nakamoto, R.J., 2005. Effects of riparian canopy opening and salmon carcass addition on the abundance and growth of resident salmonids. *Canadian Journal of Fisheries and Aquatic Sciences*, *62*(1), pp.58-67.

Wohl, E., Bledsoe, B.P., Fausch, K.D., Kramer, N., Bestgen, K.R. and Gooseff, M.N., 2016. Management of Large Wood in Streams: An Overview and Proposed Framework for Hazard Evaluation. *JAWRA Journal of the American Water Resources Association*.

Zavitkovski, J., and M. Newton. 1971. Litterfall and litter accumulation in red alder stands in western Oregon. Plant and Soil 35:257-268
Slide 25