# Streams are strongly connected to their watersheds: protection of stream networks begins at the source.


John S. Richardson

Department of Forest & Conservation Sciences

University of British Columbia
Vancouver, Canada

john.richardson@ubc.ca
http://faculty.forestry.ubc.ca/richardson/

Small streams depend on:

Shading (lower summer temperatures, less algae)

Organic matter and terrestrial invertebrate inputs

Bank stability

Large wood inputs

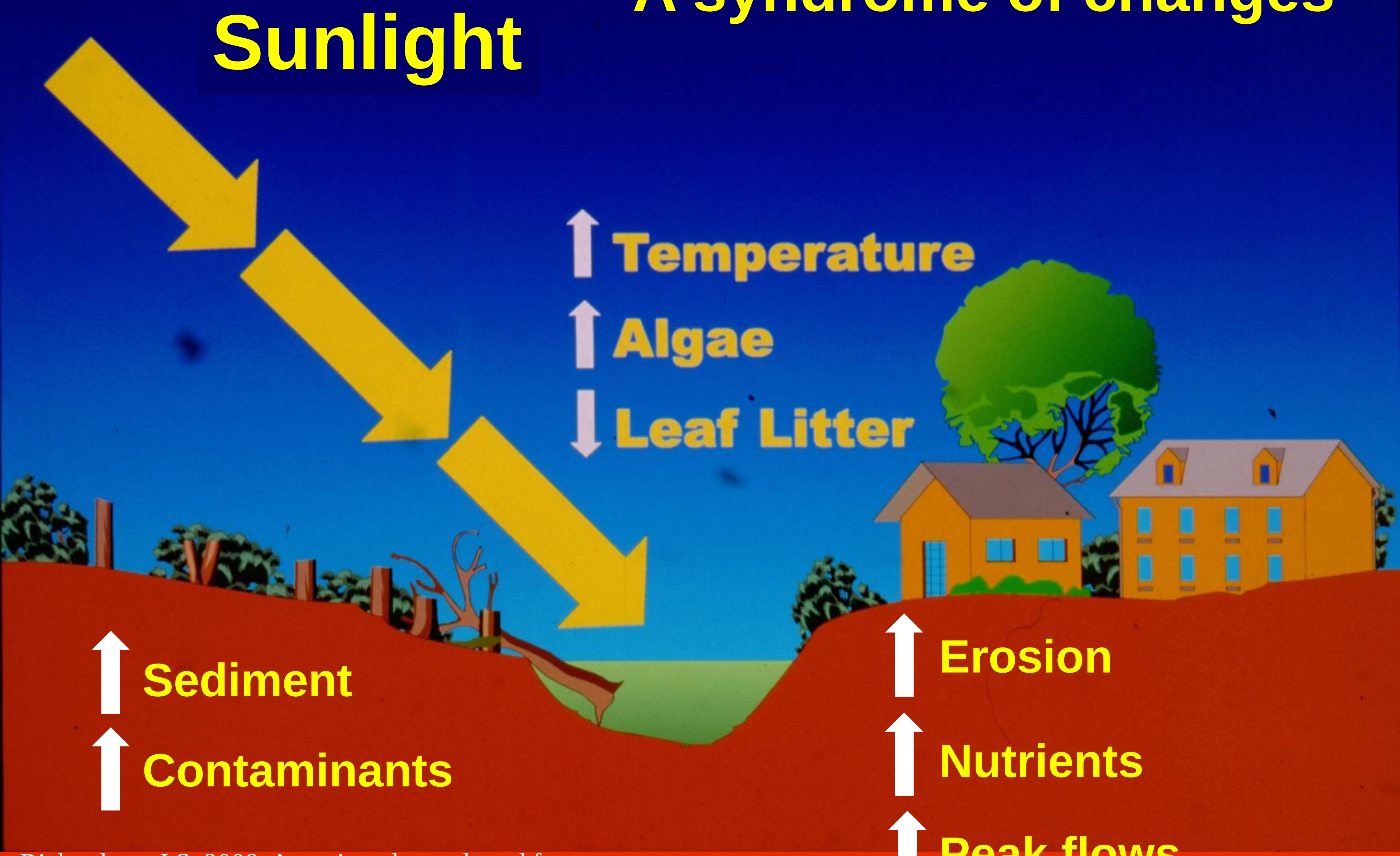
Nutrient uptake by streamside plants

Etc.

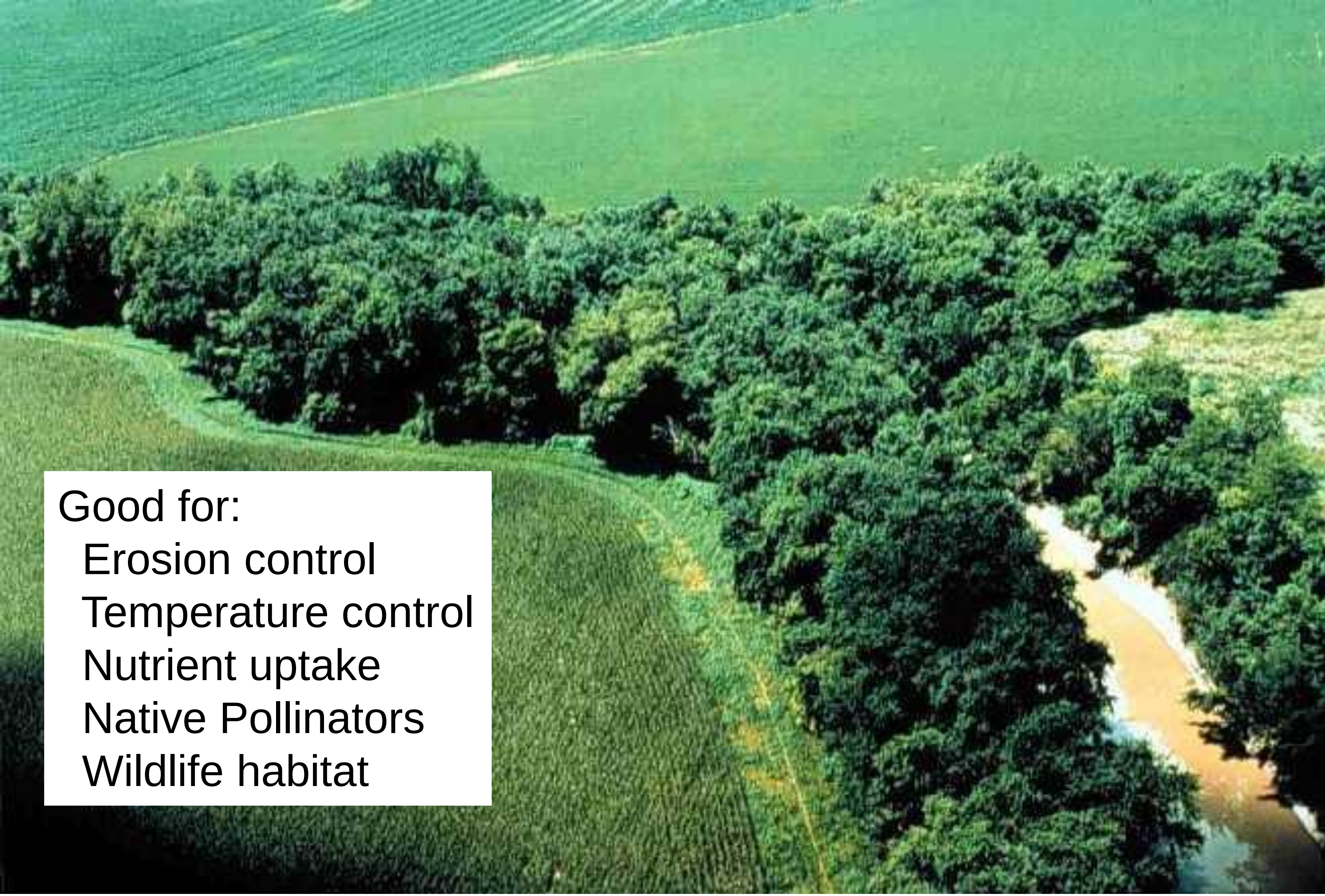
Richardson JS & Danehy RJ. 2007. A synthesis of the ecology of headwater streams and their riparian zones in temperate forests. *Forest Science* 53:131-147.

Moore RD & Richardson JS. 2012. Natural disturbance and forest management in riparian zones: Comparison of effects at reach, catchment and landscape scales. *Freshwater Science* 31:239-247.

# A syndrome of changes




Richardson, J.S. 2008. Aquatic arthropods and forestry: large-scale land-use effects on aquatic systems in nearctic temperate regions. *Canadian Entomologist* 140:495-509.




USDA

Richardson JS, Naiman RJ & Bisson PA. 2012. How did fixed-width buffers become standard practice for protecting freshwaters and their riparian areas from forest harvest practices? *Freshwater Science* 31:232-238.

# Vulnerability of source streams

High degree of coupling with surrounding landscape

Isolated

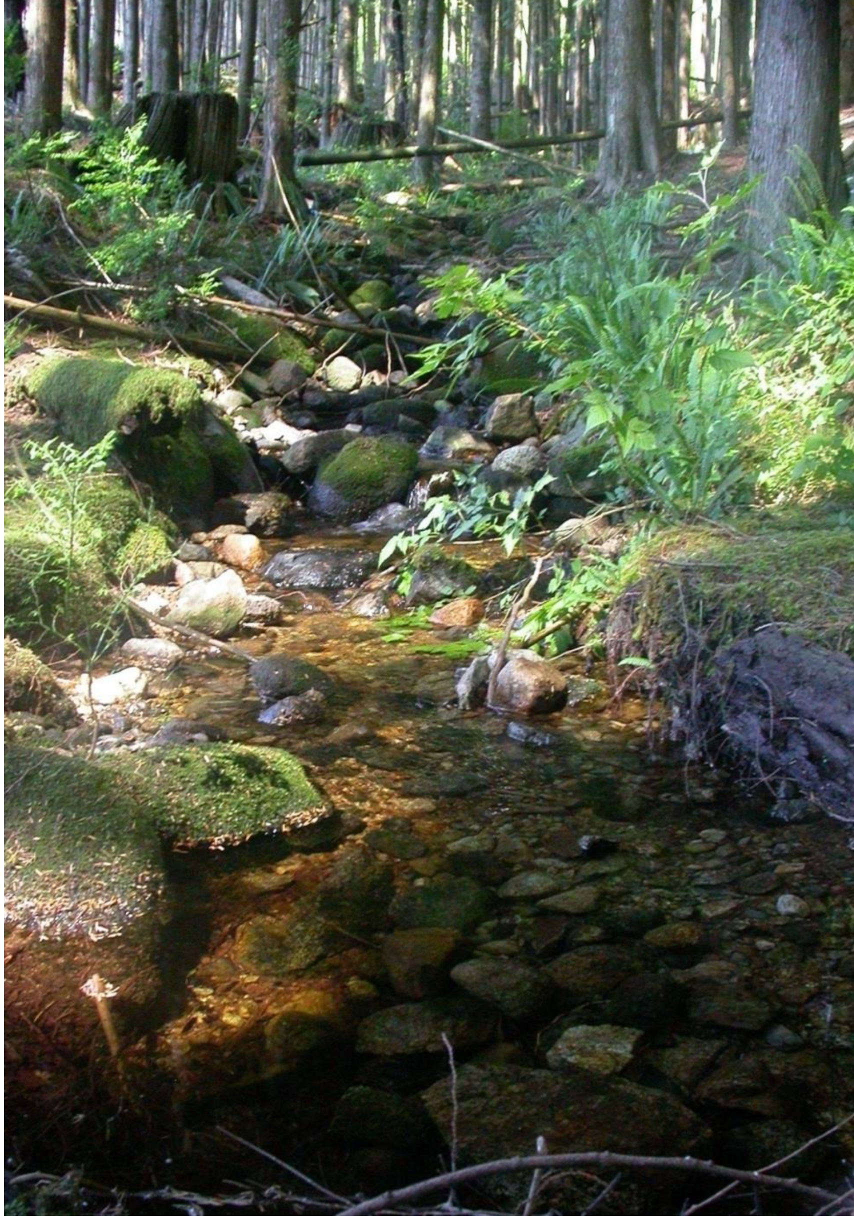
Easily channelized

Loss of important inputs (organic matter)

Increased erosion and nutrient transport

Changes to flows, their quantity, timing and quality

Increased summer temperatures



Sakamaki T & JS Richardson. 2011. Biogeochemical properties of fine particulate organic matter as an indicator of local and catchment impacts on forested streams. *Journal of Applied Ecology* 48:1462-1471.

Wipfli MS & JS Richardson. 2016. Riparian Management and the Conservation of Stream Ecosystems and Fishes. Pp. 270-291 In: Closs, G.P., Krkosek, M., & Olden, J.D. (Eds.) Conservation of Freshwater Fishes. Cambridge University Press, UK.


# Differences of “small” streams from bigger streams

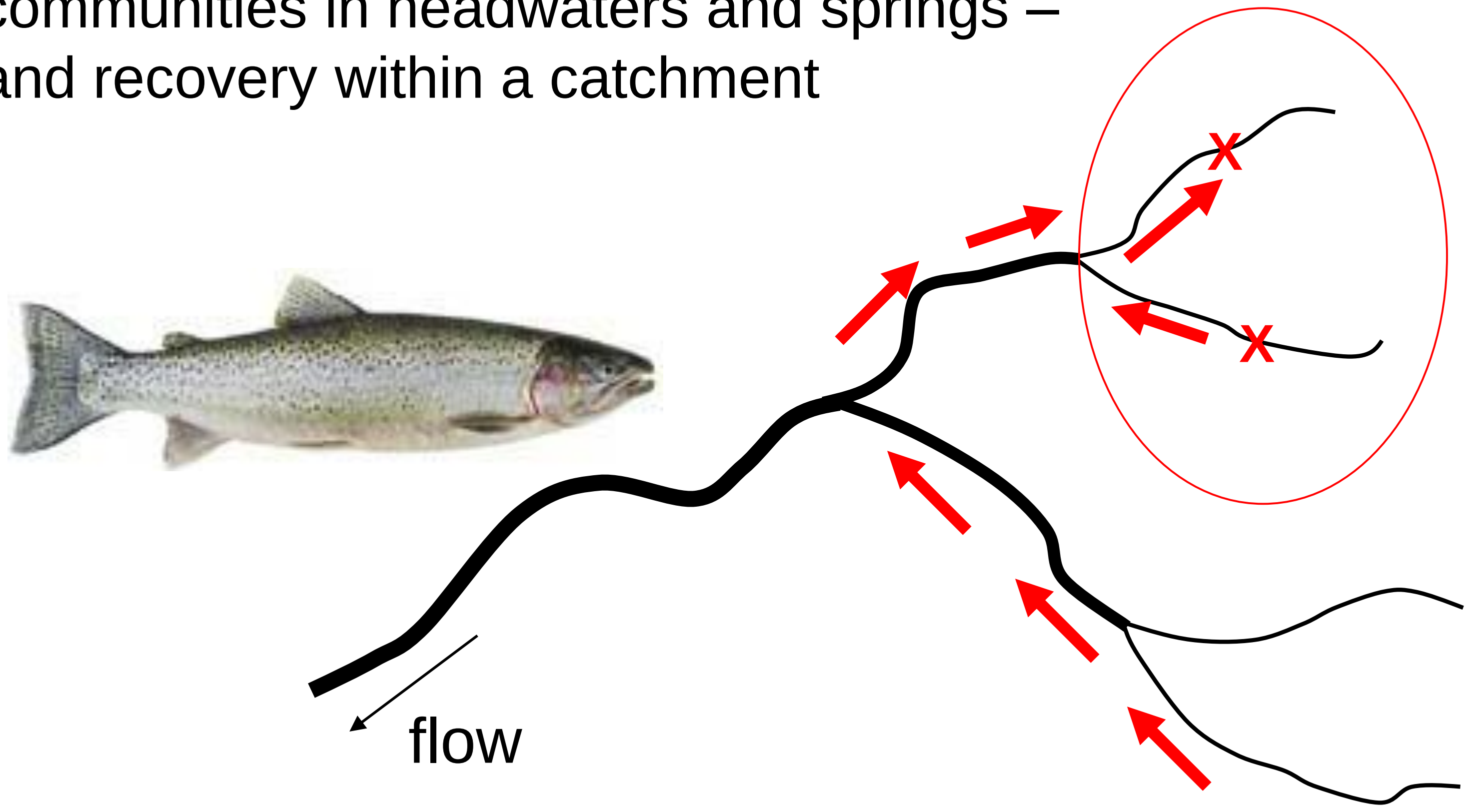

1. Different ecosystem processes
2. Unique habitat
3. Ecosystem services
4. Vulnerabilities



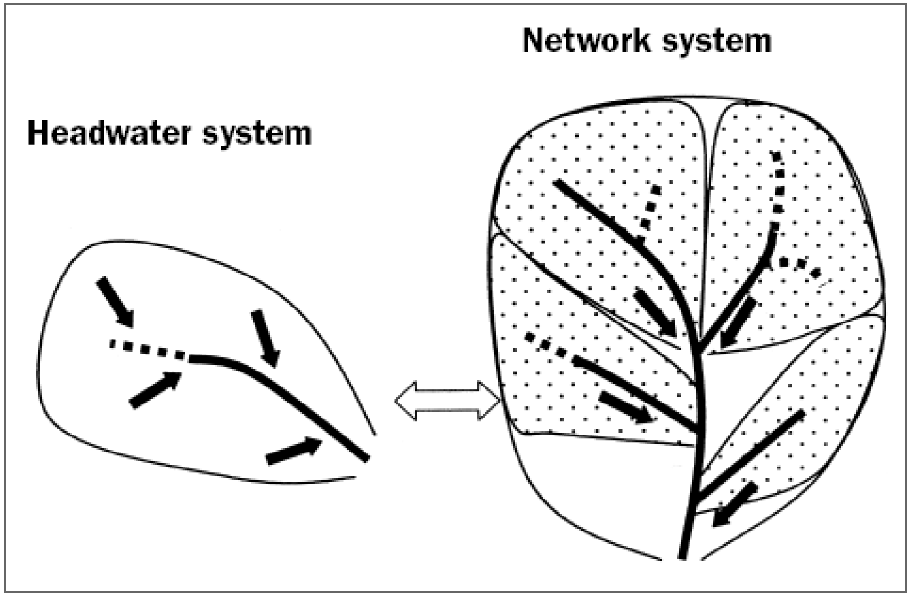
Richardson JS & Danehy RJ. 2007. A synthesis of the ecology of headwater streams and their riparian zones in temperate forests. *Forest Science* 53:131-147.

Meyer JL *et al*. 2007. The contribution of headwater streams to biodiversity in river networks. *J. Am. Water Resources Assoc*. 43: 86-103.

Vulnerability of species' populations and communities in headwaters and springs – and recovery within a catchment

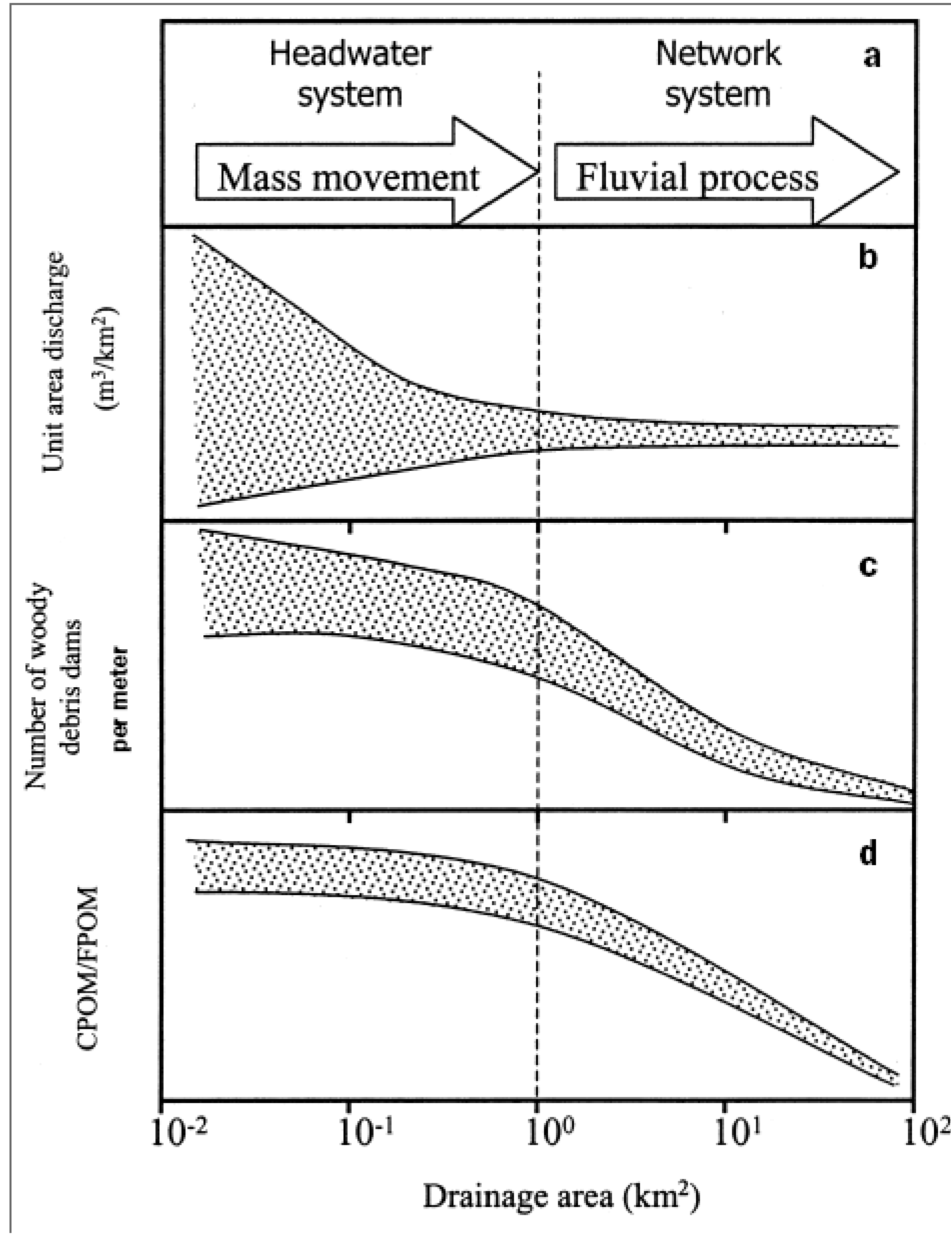



Fagan WF. 2002. Connectivity, fragmentation, and extinction risk in dendritic metapopulations. *Ecology* 83:3243-3249.

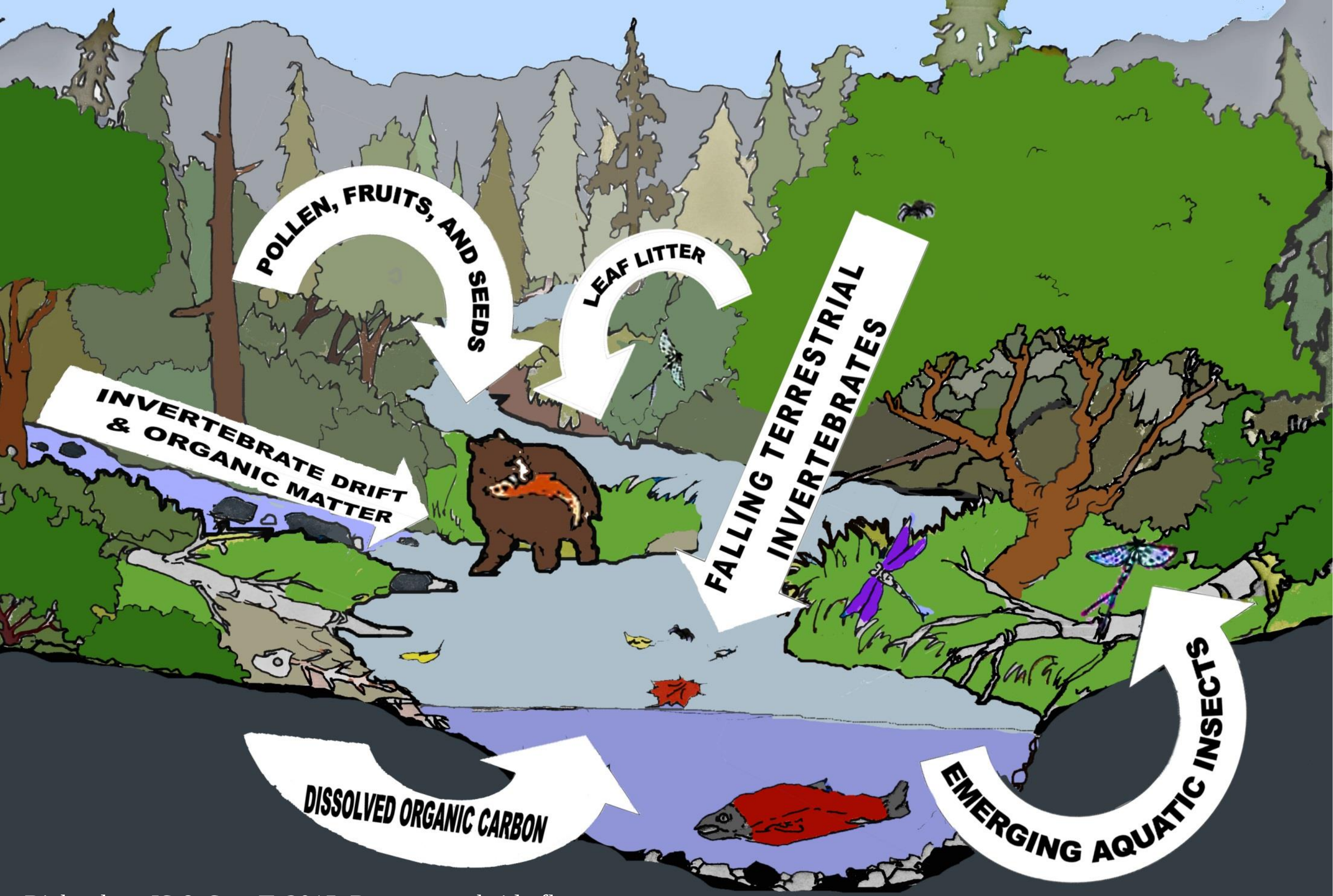



Headwaters contribute to the fluvial **network** in additive and non-additive ways

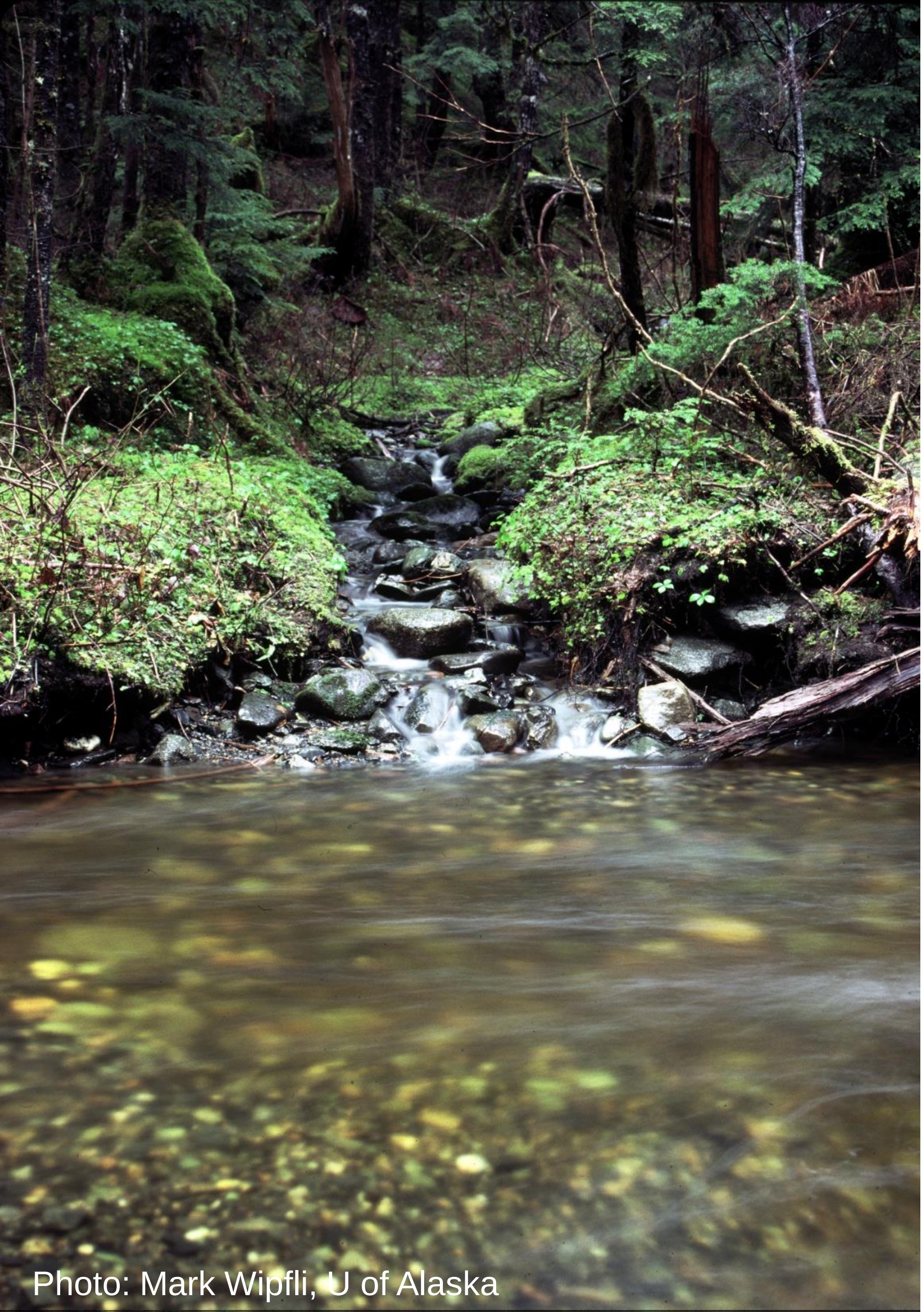
Rare, but large magnitude disturbances




Gomi T, Sidle RC & Richardson JS. 2002. Headwater and channel network -understanding processes and downstream linkages of headwater systems. *BioScience* 52:905-916.




Richardson JS & Sato T. 2015. Resource subsidy flows across freshwater-terrestrial boundaries and influence on processes linking adjacent ecosystems. *Ecohydrology* 8:406-415.




# Subsidies to downstream along the fluvial network

e.g., up to 1000 salmonids could be supported by invertebrates and organic matter from fishless streams

Wipfli MS, Richardson JS & Naiman RJ. 2007. Ecological linkages between headwaters and downstream ecosystems: transport of organic matter, invertebrates, and wood down headwater channels. *J.Am. Water Resources Assoc.* 43:72-85.

Sakamaki T & Richardson JS. 2013. Nonlinear variation of stream-forest linkage along a stream-size gradient: an assessment using biogeochemical proxies of in-stream fine particulate organic matter. *Journal of Applied Ecology* 50:1019-1027.


Headwater subsidies
Photo: Mark Wipfli

# Shifts in riparian vegetation (early seral stages) can influence stream productivity

Nutritional value

Physical differences

Timing

Size and interaction with physical retention



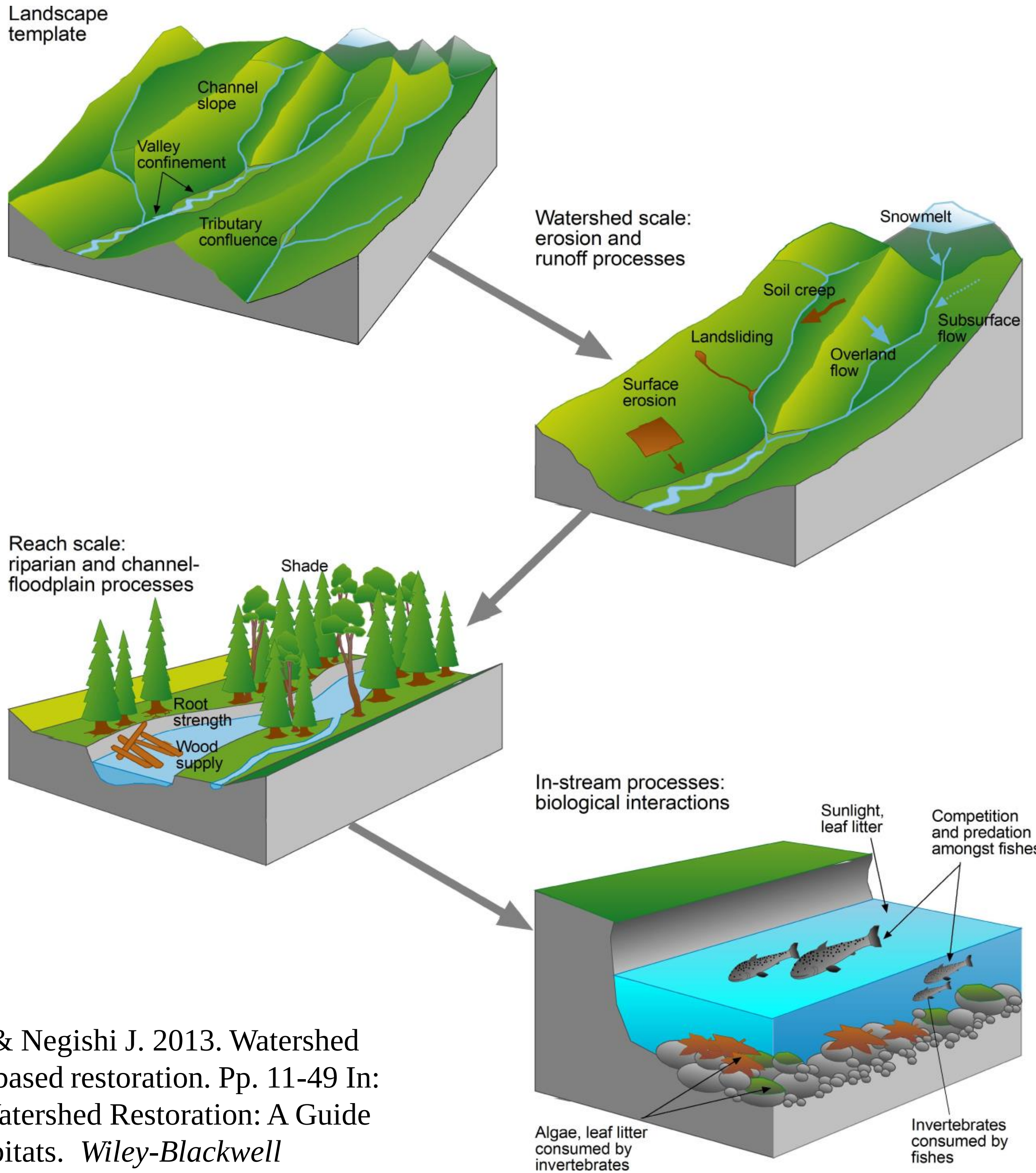

Wipfli MS & Musslewhite J. 2004. Density of red alder (*Alnus rubra*) in headwaters influences invertebrate and detritus subsidies to downstream fish habitats in Alaska. *Hydrobiologia* 520: 153-163.

Kominoski JS, Marczak LB & Richardson JS. 2011. Riparian forest composition affects stream litter decomposition despite similar microbial and invertebrate communities. *Ecology* 92:151-159.

Kiffney PM & Richardson JS. 2010. Organic matter inputs into headwater streams of southwestern British Columbia as a function of riparian reserves and time since harvesting. *Forest Ecology and Management* 260:1931-1942.

# Streams receive and integrate all the influences from the landscape

Effects of Land Use and Land Cover (LULC)

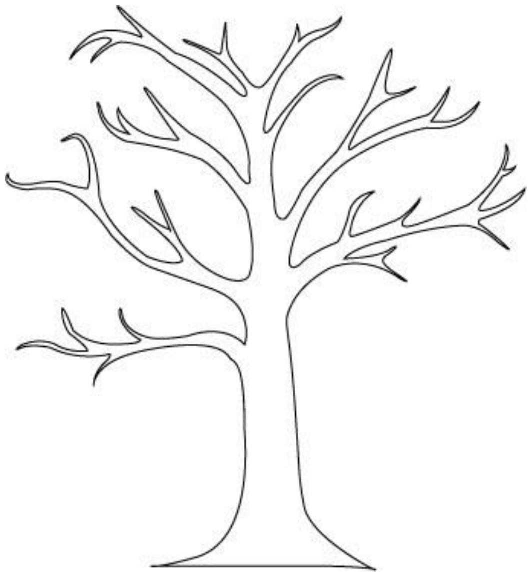



Beechie T, Richardson JS, Gurnell AM & Negishi J. 2013. Watershed processes, human impacts, and process-based restoration. Pp. 11-49 In: Roni P &T Beechie (eds.) Stream and Watershed Restoration: A Guide to Restoring Riverine Processes and Habitats. *Wiley-Blackwell*

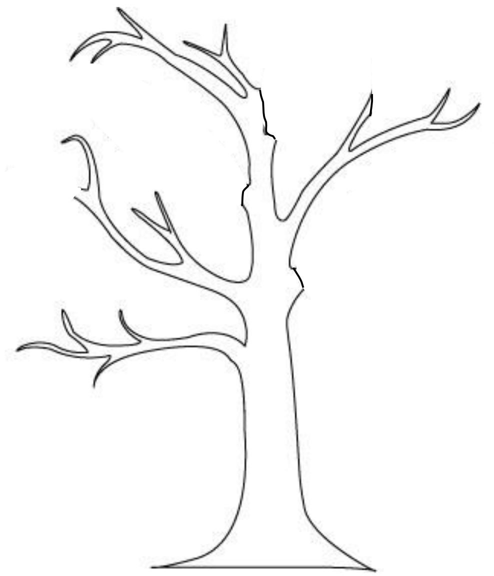
# “Trimming the tribs”

Team:

John Richardson (UBC), Dan Moore (UBC), Antoine Morin (UOttawa), Jim Buttle (Trent), Les Stanfield (expert emeritus) and Laura DelGuidice (TRCA)



2 post-doctoral fellows,1 PhD student, and a Research Associate

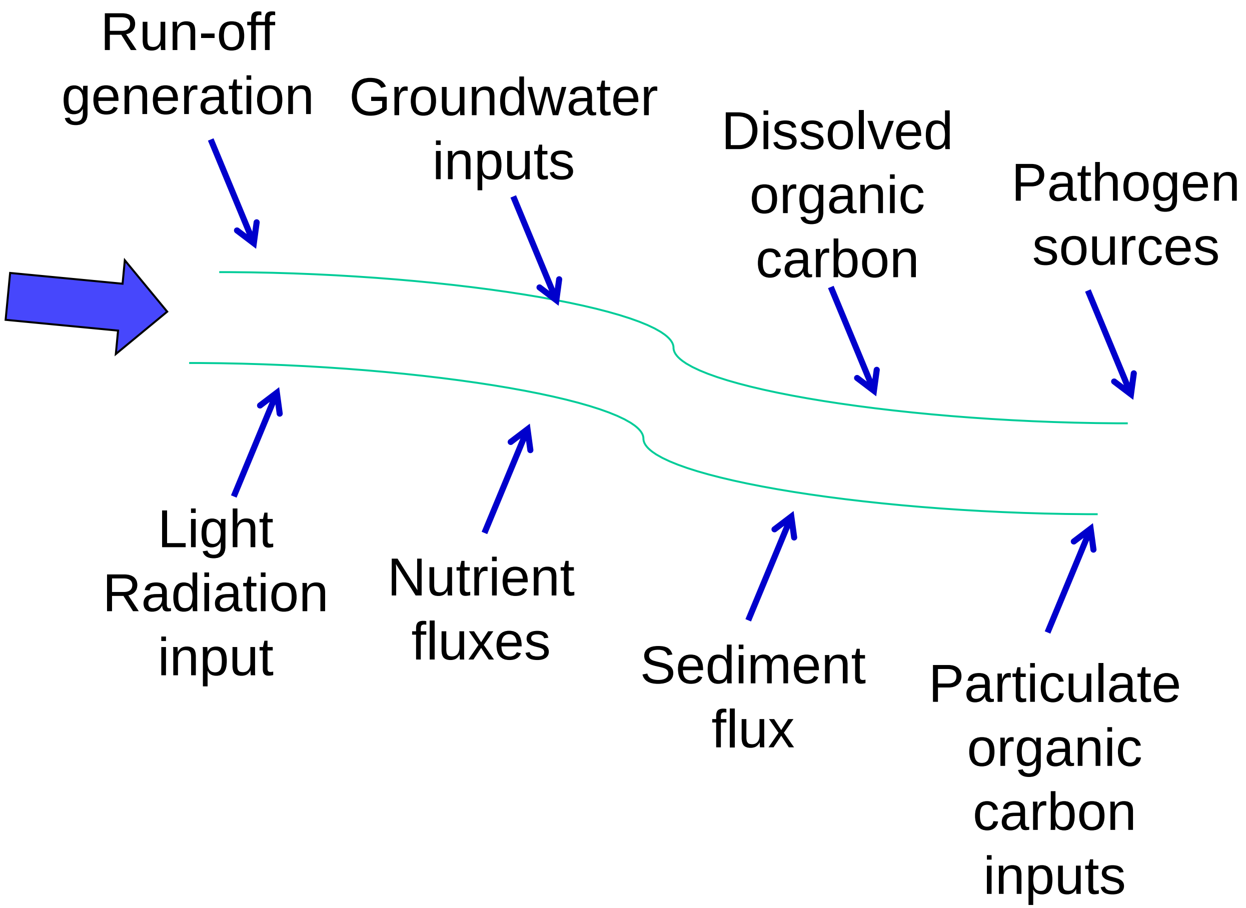


Field work began March / April 2015

Project from Oct 2014 to September 2017

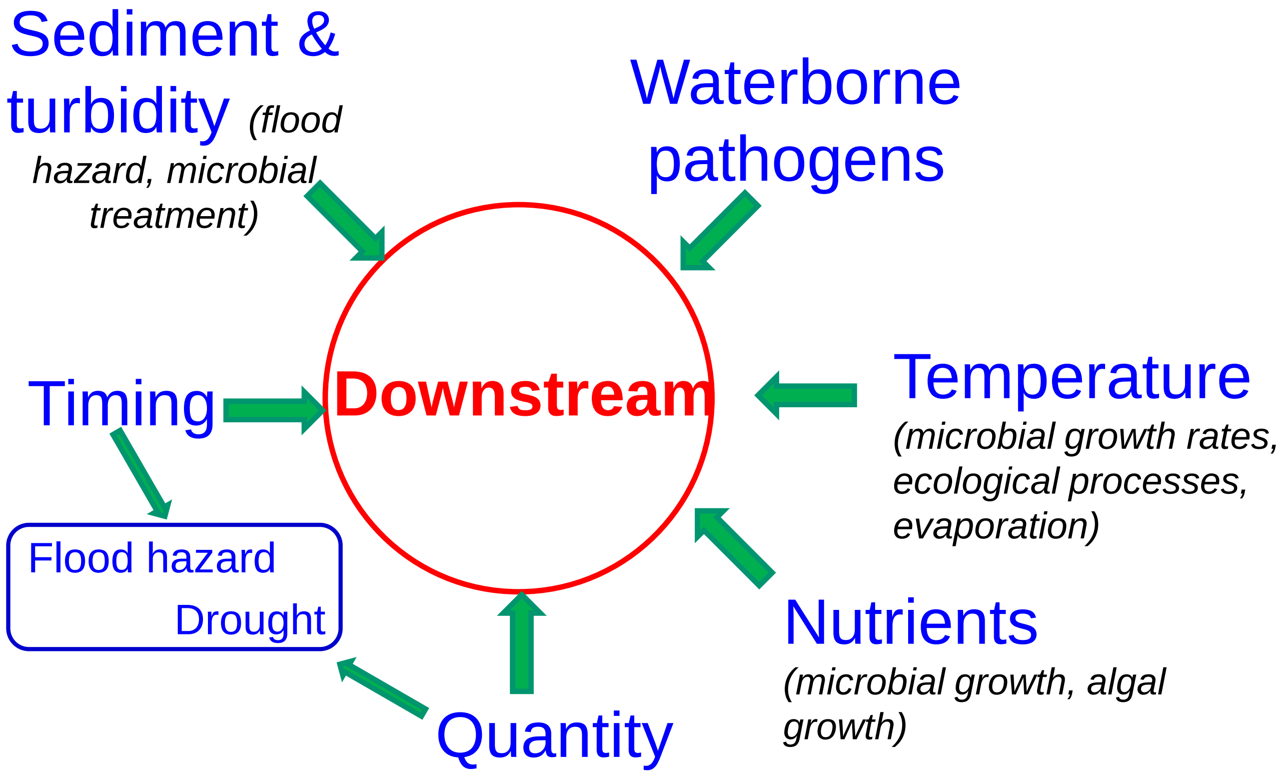
How many branches can be lost before we can detect that a stream network no longer functions properly?

# Spatially explicit catchment processes



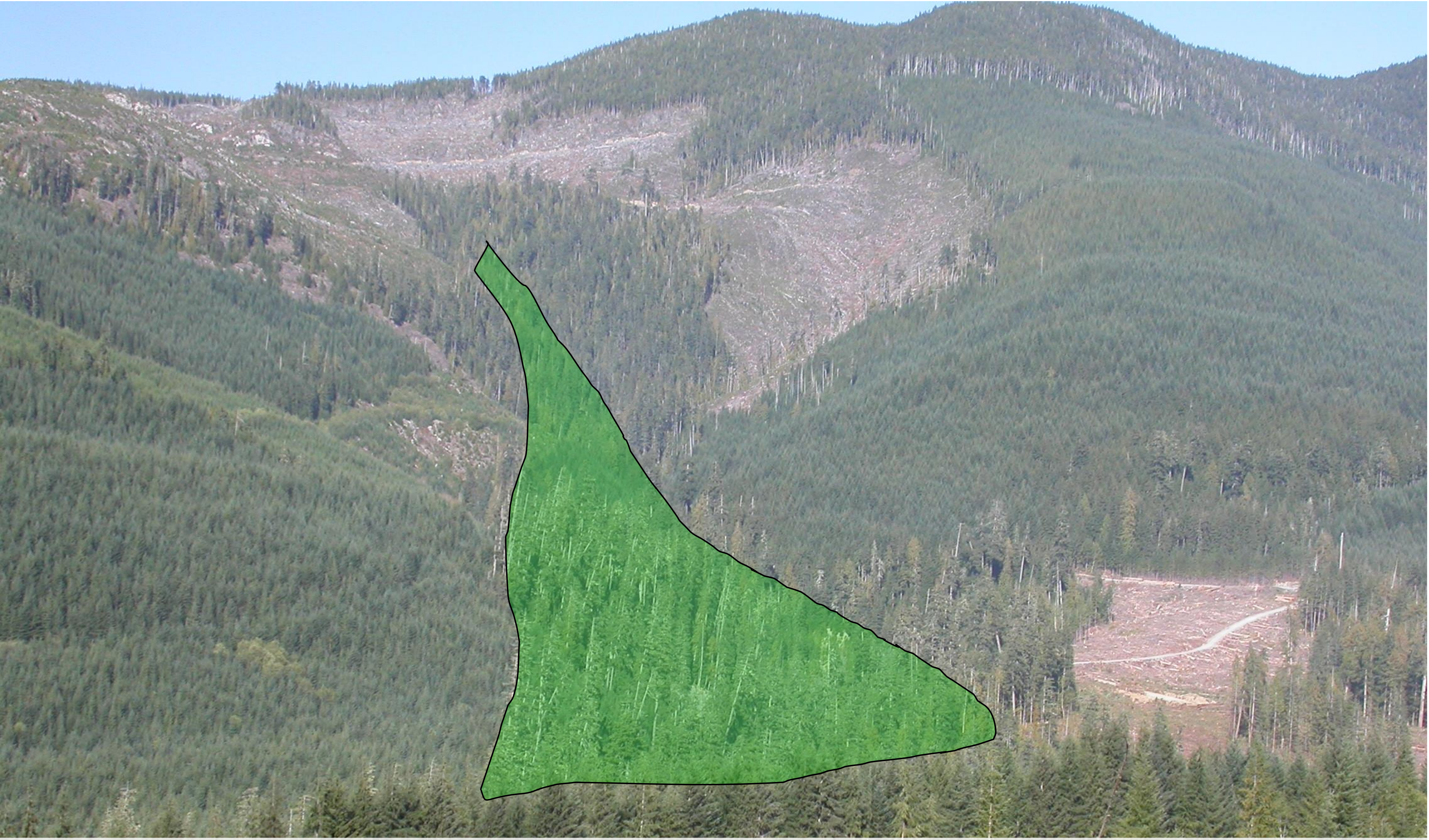

SWAT models, empirical measures

# Threats to downstream from headwater management



# Is it better to protect the source or the receiving area of a catchment?

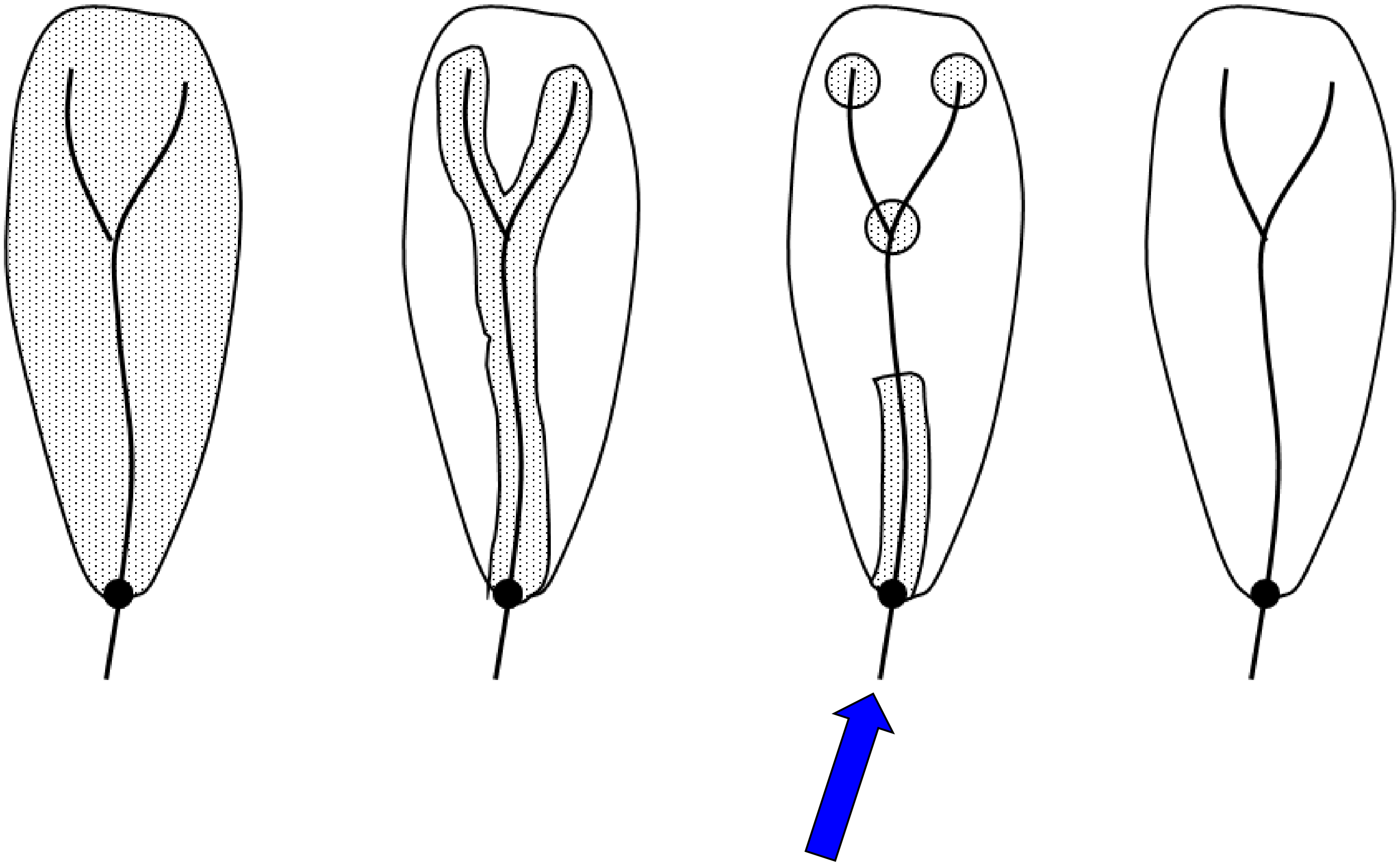
Richardson JS, Naiman RJ & Bisson PA. 2012. How did fixed-width buffers become standard practice for protecting freshwaters and their riparian areas from forest harvest practices? *Freshwater Science* 31:232-238.



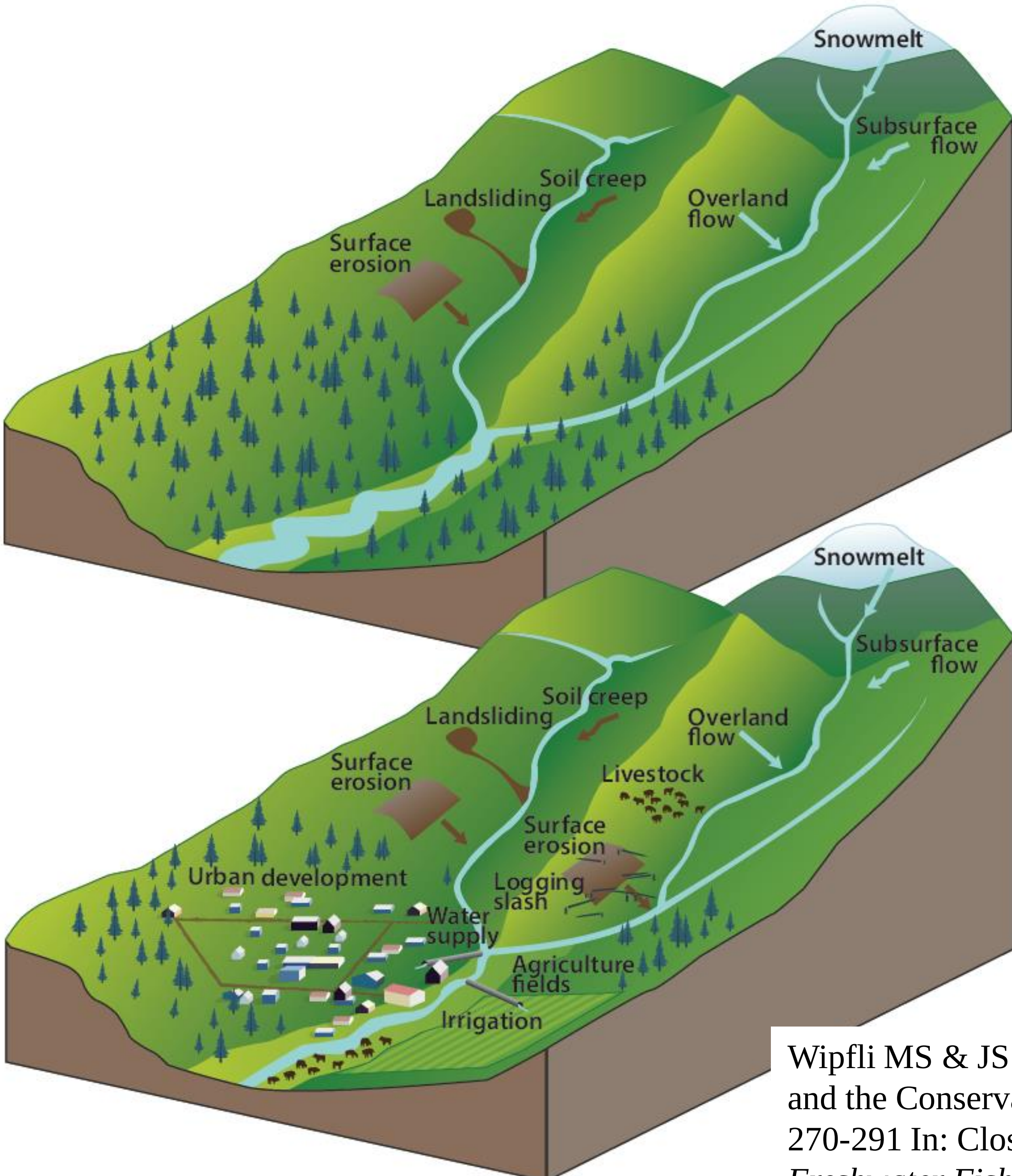
Is it better to protect the source or the receiving area of a catchment?

Is it better to protect the source or the receiving area of a catchment?

## Different ways of protecting fishless source streams in Washington State, USA



Current Forest Practices Rules




# Challenges

Cumulative effects may not be additive

Strong non-linearities

Large scaling uncertainties with specific links

We know very little about recovery after harvesting

Wipfli MS & JS Richardson. 2016. Riparian Management and the Conservation of Stream Ecosystems and Fishes. Pp. 270-291 In: Closs GP et al. (Eds.) *Conservation of Freshwater Fishes*. Cambridge University Press, UK.

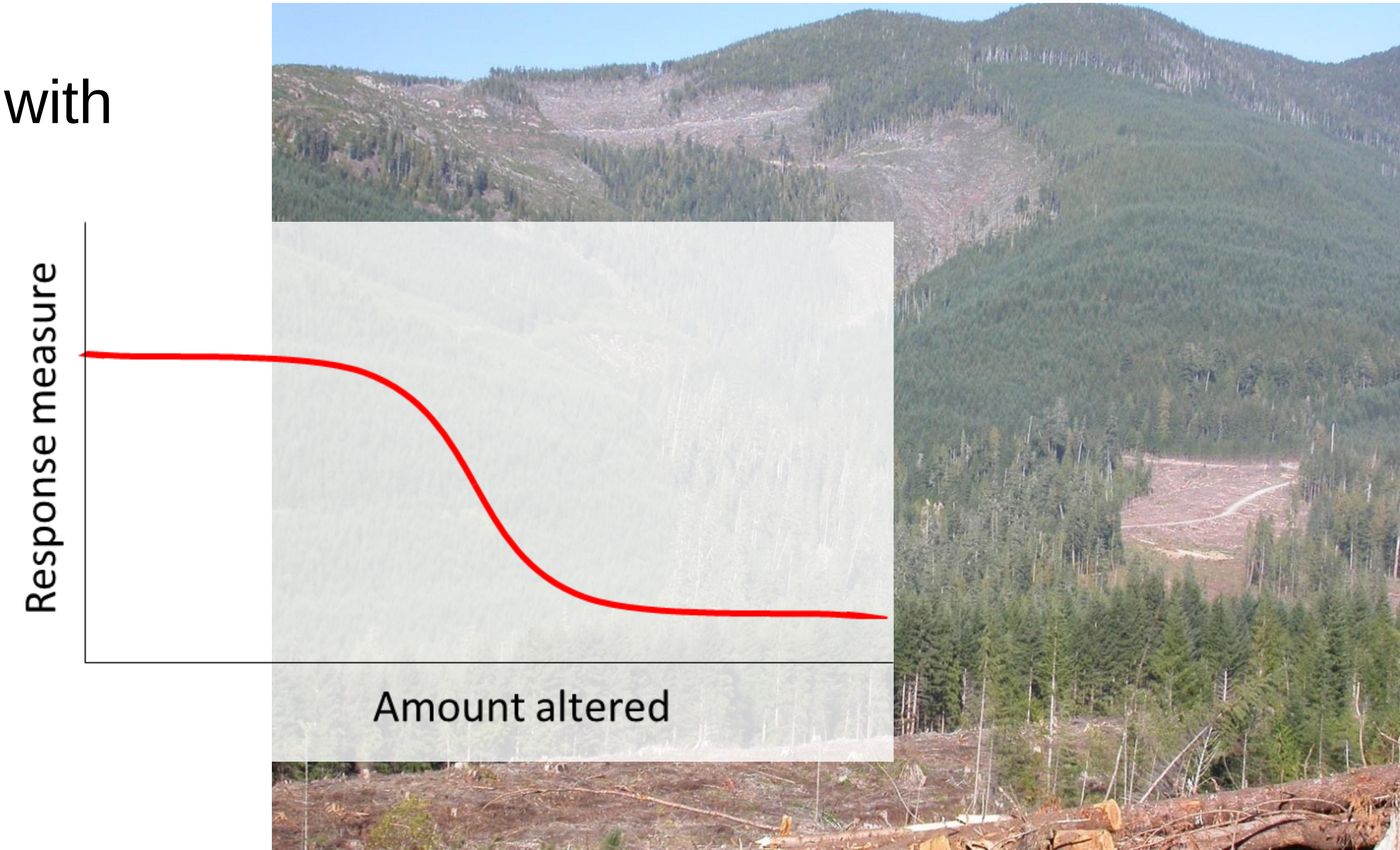
Stream G looking upstream ~5 years after harvesting of the upslope forest. This stream received a 10 m reserve on each side. Notice the amount of light reaching into the reserve, but the stream receives a large amount of shading from the shrub layer

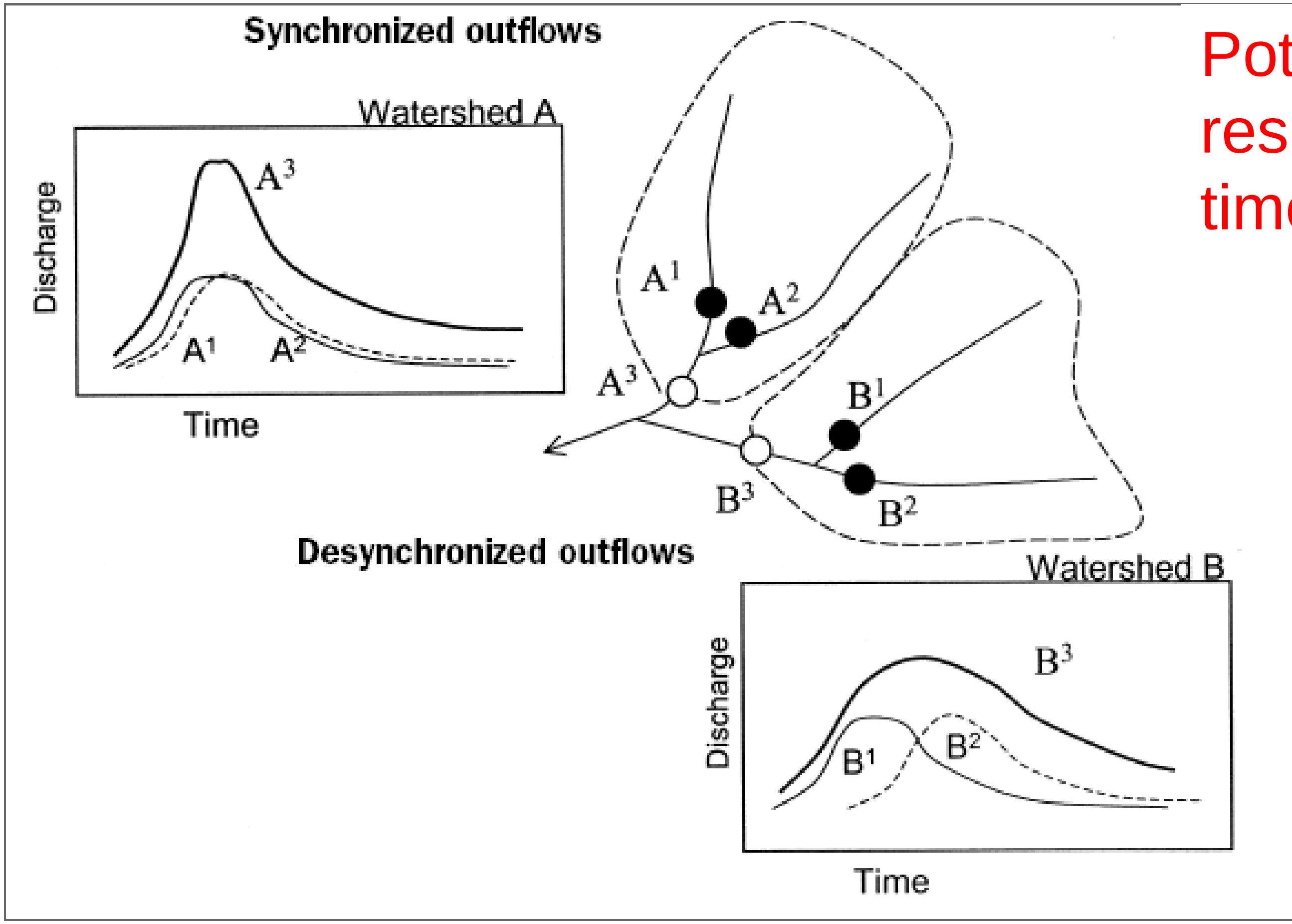
## Some difficulties linking particular tributaries to downstream effects

Cumulative effects may not be additive

Strong non-linearities

Large scaling uncertainties with specific links






Potential for lag times in responses on multiple time scales

Synchronization (or desynchronization) of hydrologic processes in network systems.

Figure adapted from Ziemer and Lisle (1998).


Gomi T, Sidle RC & Richardson JS. 2002. Headwater and channel network -understanding processes and downstream linkages of headwater systems. *BioScience* 52:905-916.

Synchronization of sediment movement in network systems. Shaded area shows sedimentation caused by landslides and debris flows.

Accumulated sediments from headwater systems may alter the formation of braided and side channels.

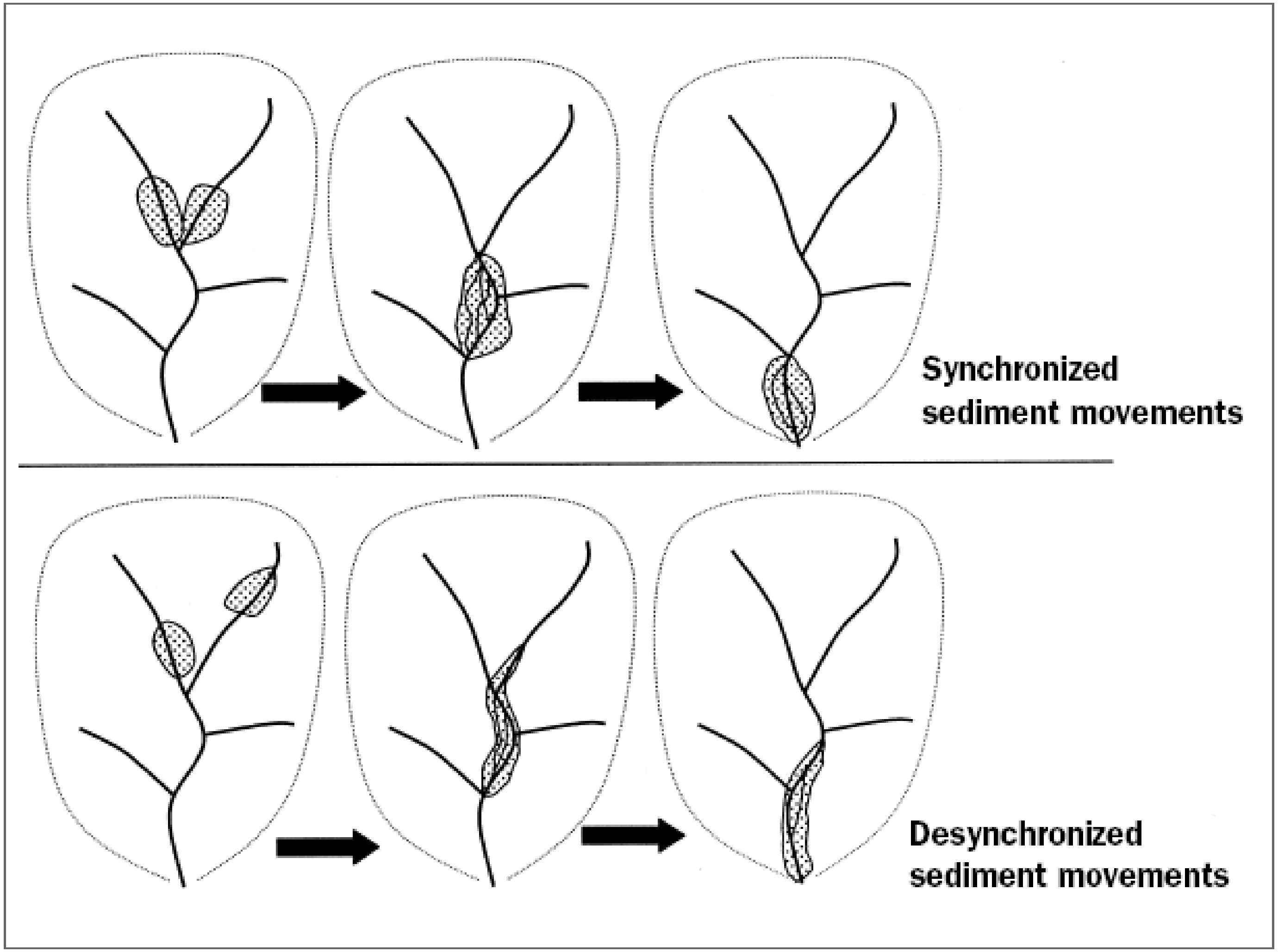
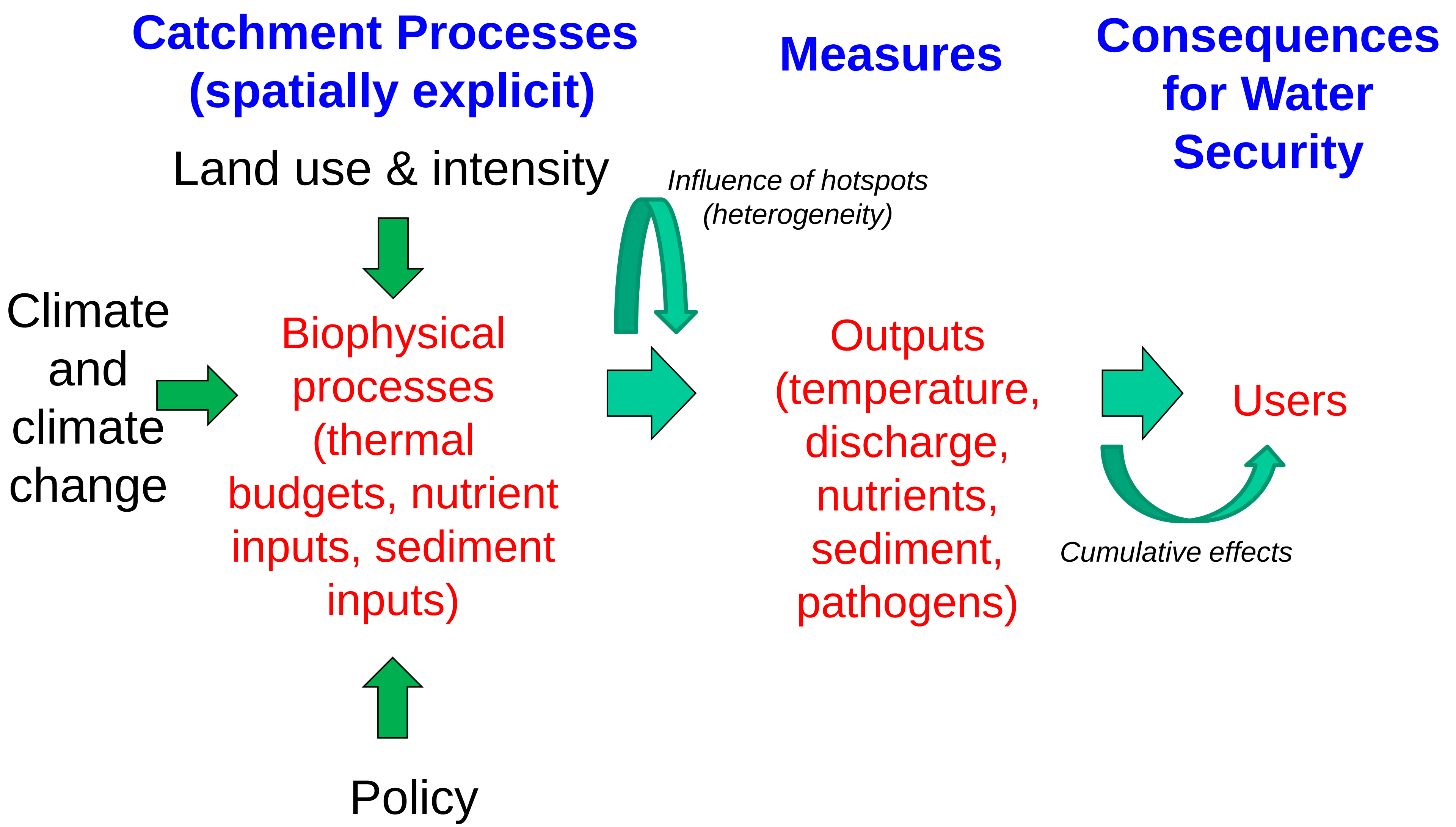



Figure adapted from Montgomery and Buffington (1998).


Gomi T, Sidle RC & Richardson JS. 2002. Headwater and channel network -understanding processes and downstream linkages of headwater systems. *BioScience* 52:905-916.




Richardson JS & Thompson RM. 2009. Setting conservation targets for freshwater ecosystems in forested catchments. Pp. 244-263 In: Villard M-A & Jonsson B-G (Eds.) Setting Conservation Targets for Managed Forest Landscapes. Cambridge University Press.

# Conclusions

Small streams the source to the catchment – impacts change inputs (organic, nutrients, sediment), disturbance regimes, flows, and recovery potential

May need to reassign riparian protection measures to protect receiving waters

Potential for cumulative effects