Recruitment and Fate of Wood in Stream and River Ecosystems: Implications for Management

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1

- Globally – important role of wood in streams and rivers widely recognized
- Several international conferences in the two decades
- Use of wood to restore and improve habitat in Europe and North America for the last 100 years

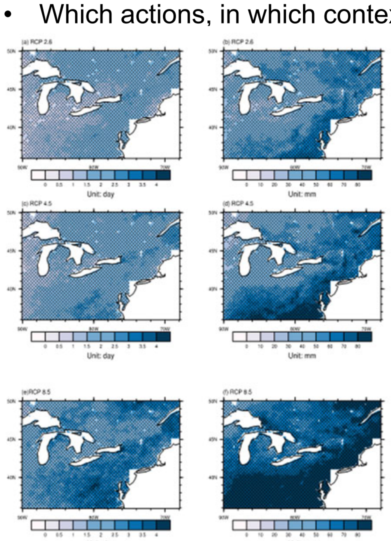
2

- Restoration – implies fixing past mistakes, restoring to some pre-disturbance/reference condition

3

In a non-stationary world:

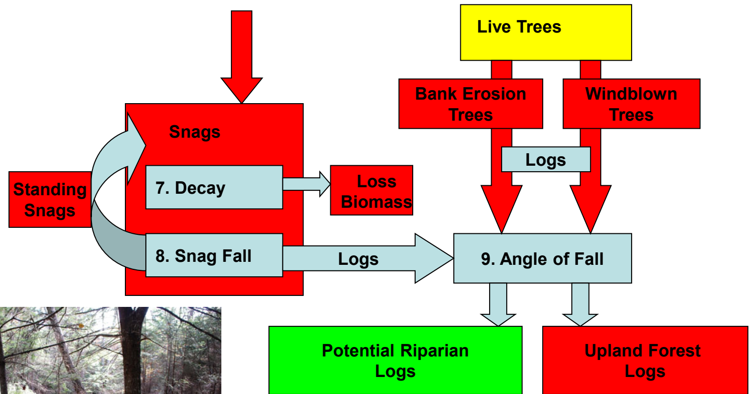
- Reference/Pre-disturbance conditions may be less helpful
- Management and practice need to look ahead, not just back
- Which actions, in which contexts, will help do both?



Ning et al. Journal of Climate (2015) 28, 8; 10.1175/JCLI-D-14-00150.1

4

How does it get there?: Recruitment of LW to stream and river channels and riparian zones



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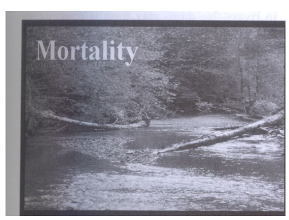
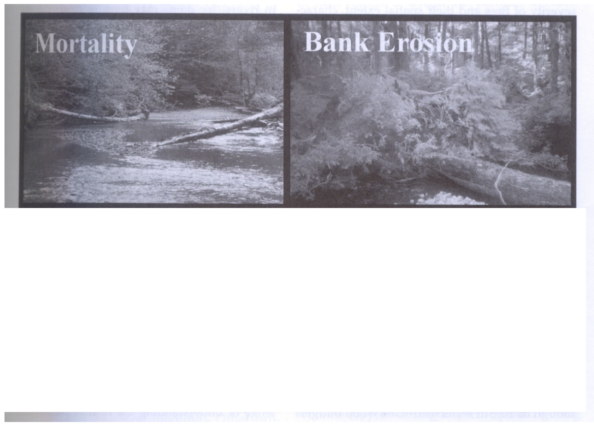


Benda, L., et al. "Wood recruitment processes and wood budgeting." *American Fisheries Society Symposium*. American Fisheries Society, 2003.

	Intrinsic	Extrinsic
Chronic	Single-tree mortality (self-thinning, senescence)	
Episodic		

6



	Intrinsic	Extrinsic
Chronic	Single-tree mortality (self-thinning, senescence)	Bank erosion
Episodic		

7

	Intrinsic	Extrinsic
Chronic	Single-tree mortality (self-thinning, senescence)	Bank erosion
Episodic	Pest/pathogen outbreaks	Extreme winds, hillslope failures, fire

8

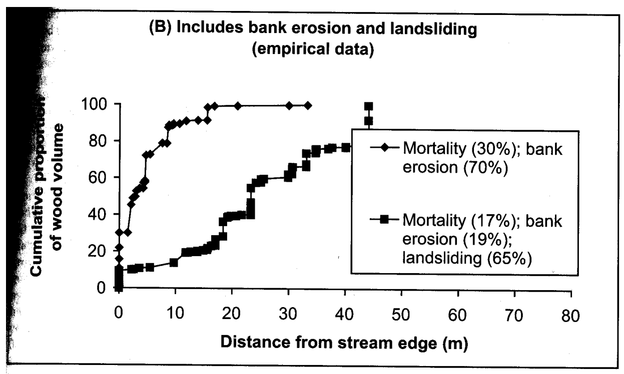
Distance from stream from which wood is recruited linked to recruitment mechanisms

- Bank erosion and individual tree and snag fall

1 -2 tree lengths

- Hillslope failures and mass-wasting

Longer distances



9

The role of chronic and episodic disturbances on channel–hillslope coupling: the persistence and legacy of extreme floods

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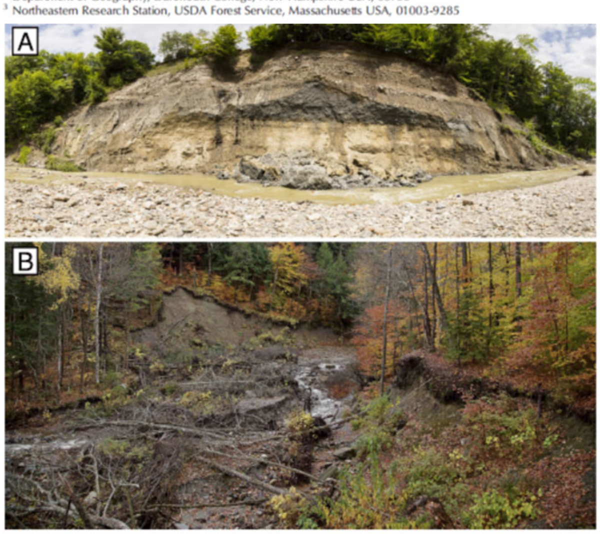
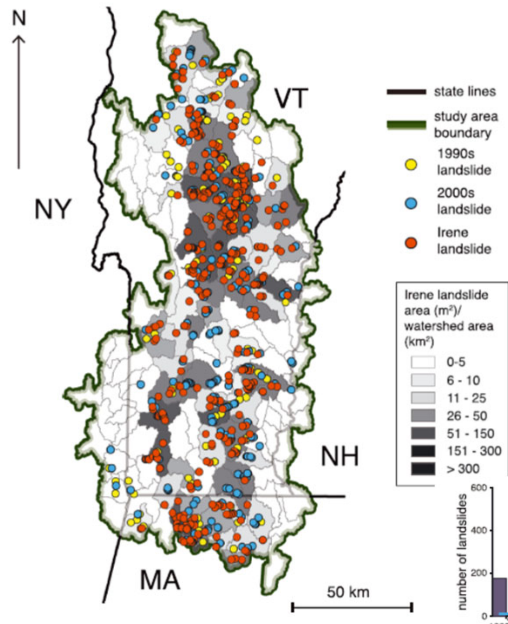
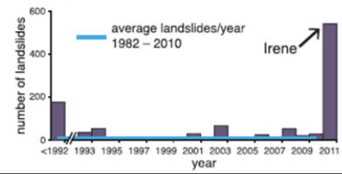


Mapped and dated landslides pre- and post-Hurricane Irene

Estimated sediment and wood yields

10



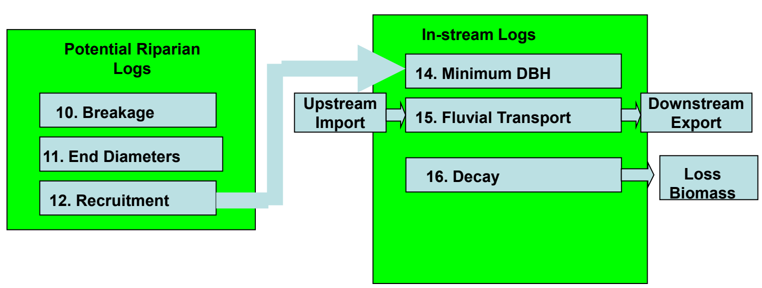


2 decades worth of landslides in a single event

Major increases in sediment and wood yield

11

How long does it stay and where does it end up?: LW retention and transport



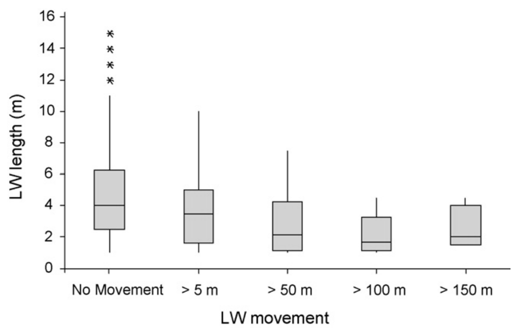
12

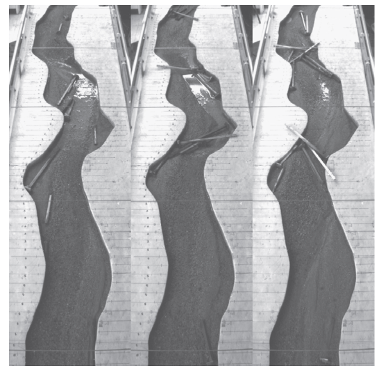
- Fluvial transport

threshold values for movement based on stream and piece size (length and diameter)

If pieces are above a threshold size they are stable

Presence of rootwads greatly increases stability





13

Wood transport, loss and retention

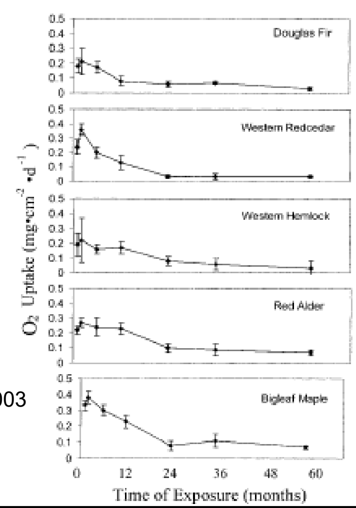
Decay as a component of loss

Wood decays much more slowly in water then it does on land

Major differences between tree species in decay rates

Trees	Decay Rates in Water proportion lost/yr
Hemlock	0.010
Balsam Fir	0.0105
Oaks	0.018
Maples, Beech	0.048

From Bilby 2003



14

How do these mechanisms translate into patterns and predictions?

Over time?
Across space?

As a function of:
- Channel and hillslope dimension and basin size
- Forest age, structure and composition

Based on:
- First principles
- Empirical studies
- Models and projections

15

Changes over time

Long time scales

- Takes a long time for existing wood to leave the channel (except if it's removed)
- " grow to recruitable/retainable size
- " for wood to recruit (complex series of stochastic and episodic processes)

16

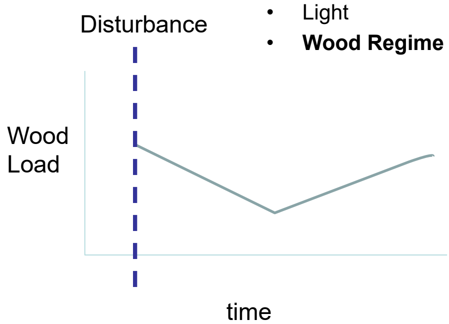
Effects of Forestry and Land Use Change

- Water Yield and Flow Variability
- Nutrient Loss
- Fine Sediment
- Temperature
- Light
- **Wood Regime**

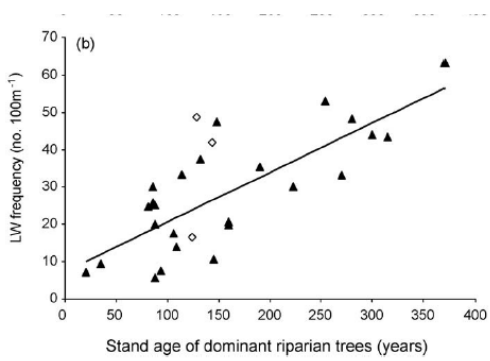
years

decades

centuries



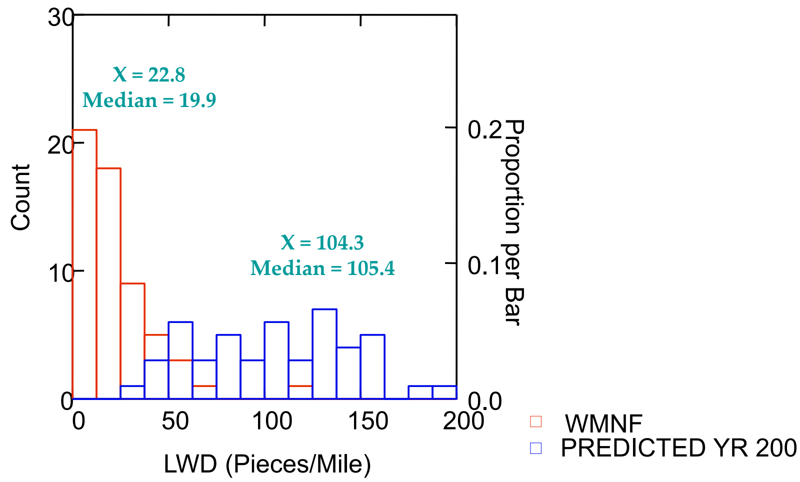
17



Response variable factors in model	AIC_c weight	p-Value	r^2	Equation
LW volume (m^3) per 100 m of stream				
Stand age	0.461	<0.0001	0.80	$\log_{10}(\text{LWvol} \times 100\ \text{m}^{-1}) = (0.0036 \times \text{stand age}) - 0.2281$
Stand age + gradient	0.118	<0.0001	0.80	$\log_{10}(\text{LWvol} \times 100\ \text{m}^{-1}) = (0.0036 \times \text{stand age}) + (0.0322 \times \log_{10}(\text{gradient})) - 0.1922$
Stand age + watershed area	0.112	<0.0001	0.80	$\log_{10}(\text{LWvol} \times 100\ \text{m}^{-1}) = (0.0036 \times \text{stand age}) + (-0.0071 \times \ln(\text{watershed})) - 0.2141$
Stand age + bankfull	0.111	<0.0001	0.80	$\log_{10}(\text{LWvol} \times 100\ \text{m}^{-1}) = (0.0036 \times \text{stand age}) + (-0.0014 \times \text{bankfull}) - 0.2208$

Warren et al. 2009

18



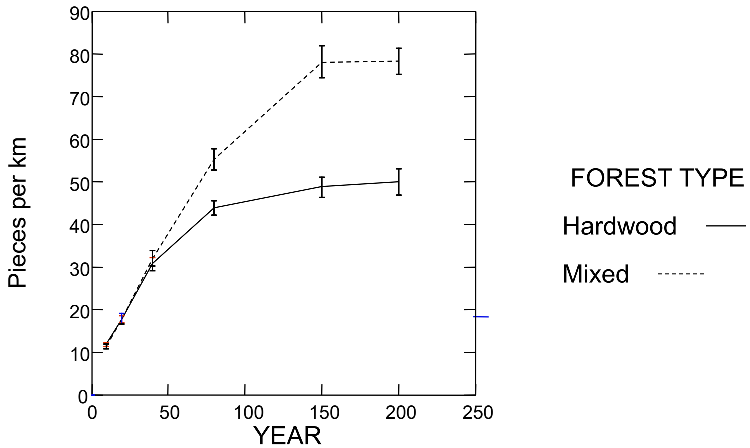
Nislow, Keith. "Riparian management: alternative paradigms and implications for wild salmon." *Salmonid fisheries: Freshwater habitat management* (2010): 164-182.

19

Influence of forest composition across sites and regions

	Growth Rate and Stem Density	Maximum Size	Decay Rate	Shade Tolerance	Flood tolerance
Eastern White Pine	Fast, high	Very Large	Slow	Intolerant	Intolerant
Northern Red Oak	Fast, low	Large	Moderate	Somewhat Tolerant	Intolerant
Eastern Hemlock	Slow, high	Large	Slow	Tolerant	Intolerant
Sugar Maple	Mid, low	Large	Fast	Tolerant	Intolerant
American Beech	Slow, low	Large	Fast	Tolerant	Intolerant
Quaking Aspen	Fast, high	Small-Medium	Very Fast	Intolerant	Intolerant
Green Ash	Mid, low	Medium	Fast	Somewhat tolerant	Tolerant

20



21

Downeast Maine

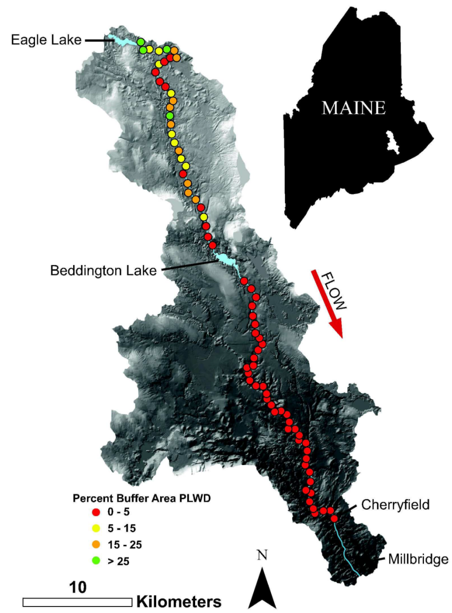
- Some of the lowest observed regional loading rates

22

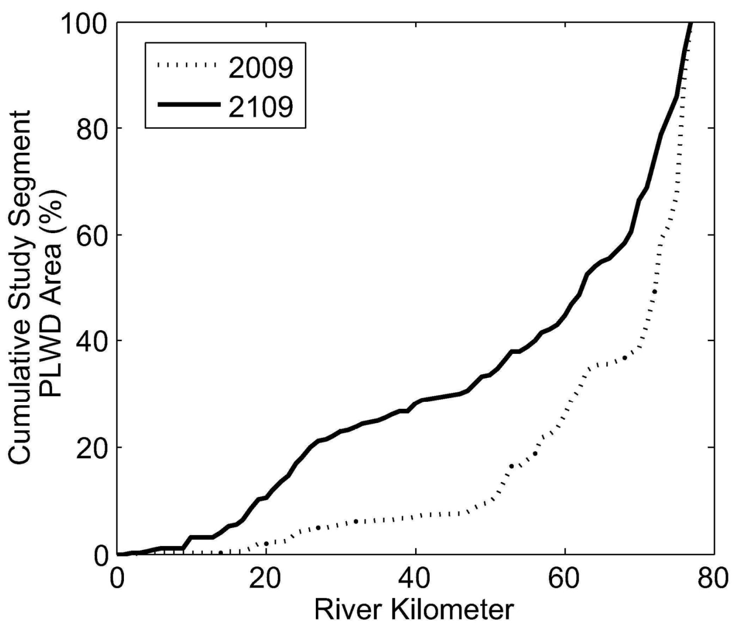
Intrinsic limitation

- Modest maximum tree sizes and slow rates of growth
- Disconnect between recruitment mechanisms and sources (Kasprak et al. 2010)
- Limitation on role of wood (low loading, unstable, unimportant relative to other sources of roughness)

- BUT wood loads take a long time to recover to 'pre-disturbance levels

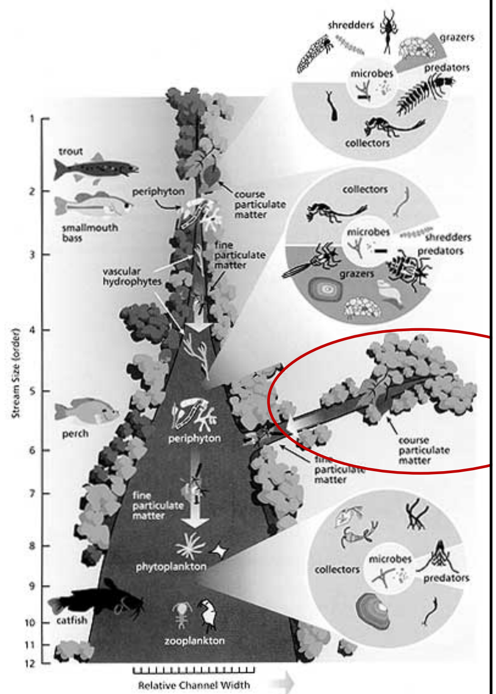


23



24

- Longitudinally (headwaters to mouth)



Vannote et al. RCC

25

Headwaters

26

Headwaters

= low sinuosity = low rates of bank erosion

27

Headwaters

= small basin size = narrow channels = lower threshold piece size for stability

= steep valleys = high vulnerability to slope failures

Yield relatively high recruitment rates and standing stocks, dispersed distribution of wood pieces

28

Mid-reaches and larger rivers

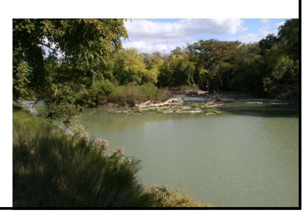
29

Mid-reaches and larger rivers

= wider channels = higher threshold piece size for stability

= wood clumped in jams

= higher sinuosity = higher rates of bank erosion

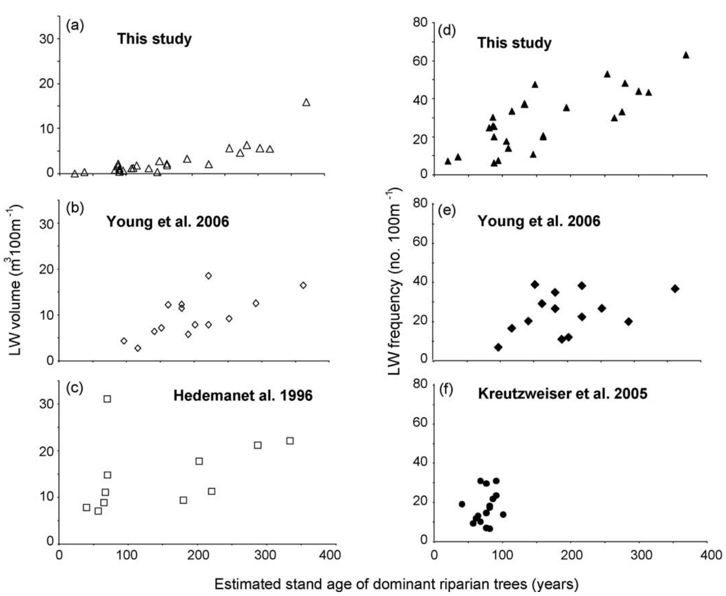


30

Where do we stand?

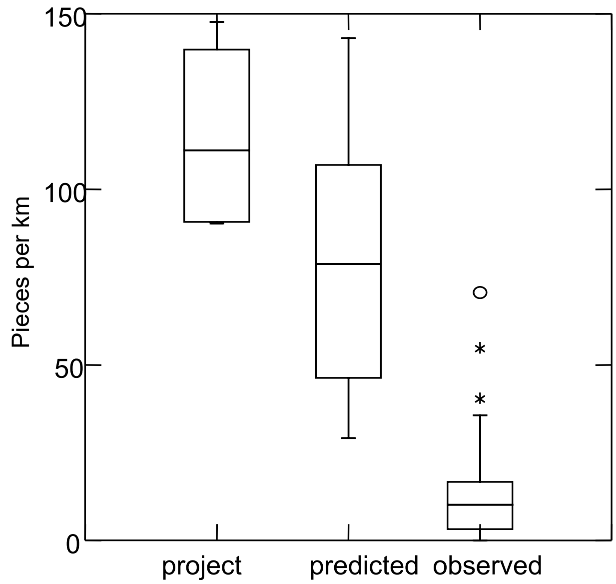
- Both empirical and mechanistic models indicate increasing wood loads with increasing stand age in much of the east
- General justification for conservation/restoration

31



Warren et al. Forest Ecology and Management 2009

32



33

Where do we stand?

- Management targets and natural ranges of variability

At the reach level (< 1km), substantial intrinsic variability

At this scale there is no ‘unacceptable’ loading rate

Not the appropriate scale for inventory and assessment

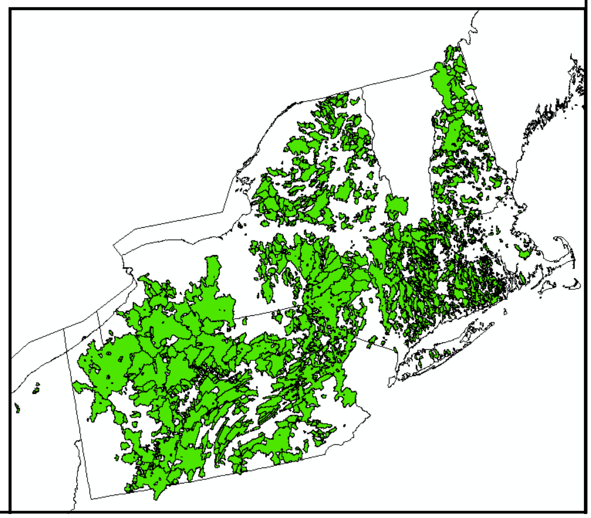
How can we use new technology to make these assessments

34

Appropriate Scale

Headwater salmonid populations – persist in small catchments (1-5 km2)

At this scale, purposeful additions can make a big difference on overall LW loads

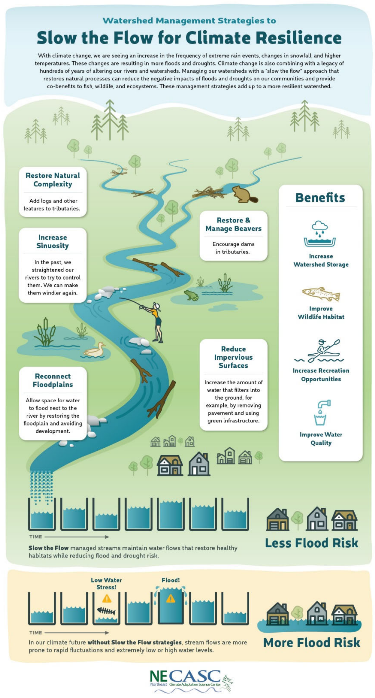


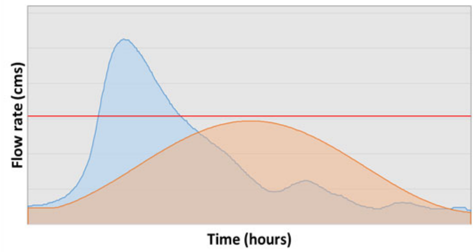
35

Where do we stand?

- Episodic/catastrophic vs. chronic recruitment mechanisms in a changing climate
- Large wood as an element of climate adaptation

36





Nislow, K.H., Magilligan, F.J., Saleeba, M. and Palmer, R.E., 2023. Slowing the flow for climate resilience in human-dominated landscapes. *In Press*

37

Management Action	Mechanism	Increased local flooding	Scale	Conservation Targets	Watershed Position
Impervious Surface Conversion	Soil and Groundwater Storage	No	Watershed	Terrestrial	Lowlands
Increasing Channel Sinuosity	Increased effective channel length	Not necessarily	River Corridor	Aquatic	Lowlands/ Uplands
Large Wood Addition/ Restoration	Increased channel roughness	Yes	River Channel	Aquatic	Uplands
Floodplain/Riparian Forest Restoration	Increased bank and floodplain roughness	Yes	River Corridor	Aquatic/ Terrestrial	Lowlands
Watershed Forest Restoration	Increased Canopy Interception	No	Watershed	Terrestrial	Uplands
Wetland Restoration (Including Beaver Restoration)	Storage in wetlands and ponds	Yes	River Corridor	Aquatic/ Terrestrial	Lowlands/ Uplands (Beaver)
Floodplain Reconnection	Storage in floodplains	Yes	River Corridor	Aquatic/ Terrestrial	Lowlands

38

39